HUMAN OSTEOLOGY

A Laboratory and Field Manual

THIRD EDITION

By

WILLIAM M. BASS

1987

Volume Editor

Michael K. Trimble

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Human Osteology: A Laboratory and Field Manual originally was published in 1971 under the title Human Osteology: A Laboratory and Field Manual of the Human Skeleton as *Missouri Archaeological Society, Special Publication* No. 2. Forerunner to the 1971 publication was a 1962 mimeograph release entitled Field Handbook of the Human Skeleton, by Robert F. G. Spier, University of Missouri, and William M. Bass, then of the University of Kansas. Dale R. Henning edited the handbook. Bass' contribution was a section entitled "The excavation of human skeletal remains," and Spier contributed revised versions of two serialized articles that had appeared in the *Missouri Archaeological Society Newsletter*—"Know your bones" (between December 1950 and May 1953 [Newsletter nos. 44-45, 57-60, and 62-69]), and "Determination of age and sex of skeletal remains" (between November 1956 and May 1958 [*Newsletter* nos. 106-113, 117, 118, 120, and 122]).

In appreciation to my Doctoral Committee

From the University of Pennsylvania:

Carlton S. Coon
Loren C. Eiseley
Wilton M. Krogman (chairman)

From the Smithsonian Institution:

Frank H. H. Roberts, Jr.
T. Dale Stewart
Waldo R. Wedel

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PREFACE TO THE FIRST EDITION

I have long been interested in the human skeleton and for some years have taught physical anthropology and anatomy. In helping students to understand anatomical form and structure, landmarks, and terminology, I have become increasingly aware that although physical anthropology is one of the oldest studies of man, there are few if any publications directed specifically to workers in this field that give sufficient information for the identification and analysis of the bones of the human skeleton.

The present book is an attempt to remedy this deficiency. It does not pretend to be a complete summary, for such would take much more space than is desirable in a manual. It does attempt to present basic anatomy of the bones, major anatomical landmarks, criteria for determining right or left sides of paired bones, basic anthropometric measurements, and indices and comparative data drawn from the literature to make the indices, and thus the anthropometric analysis, more meaningful. Variations or anomalies are given for a few bones.

This manual is intended for the use of both students and professionals in the field as an aid to the identification of human bone and in the laboratory as an aid to identification, study, and analysis. The arrangement is such that it can be used as a text in the osteological section of either an introductory or advanced course in physical anthropology or archaeology.

I acknowledge with pleasure the assistance of my many students who, over the past eleven years, have offered criticisms and suggestions on how to present the data in a clear and understandable manner. Three books have been published by colleagues in this general area of science but none with the same approach as this manual: J. E. Anderson—*The Human Skeleton, Manual for Archaeologists;* J. Kelso and G. Ewing—*Introduction to Physical Anthropology Laboratory Manual;* and D. R. Brothwell—*Digging up Bones*. To them I acknowledge some ideas regarding format. None approach the identification of the human skeleton from the aspect of growth as is done in this manual.

Usually about half of the human skeletons from an archaeological site are subadults. Without this manual it is difficult to find illustrations and information to identify subadult material. In addition, this manual presents each bone separately, along with information on its growth, age, sex, and measurements. This makes the manual easier to use.

To T. Dale Stewart I am indebted for reading the manuscript and making many meaningful suggestions as to format and content, and for his encouragement and help over the years. M. Dale Kinkade, William Clemens, and Douglas H. Ubelaker have read the manuscript and offered many helpful suggestions. In addition, Ubelaker prepared most of Chapter 4 on human dentition. I appreciate the work of Madelyn Jenks in the preparation of the manuscript. Peggy Grinvalsky illustrated most of the bones.

William M. Bass
1971

PREFACE TO THE SECOND EDITION

I wish to express my appreciation to those colleagues and students who have made suggestions to improve the quality of this book. Attempts have been made to correct the errors and to make additions in the final chapter. Skeletal biology continues to be a dynamic area of study. I wish to thank Annette Blackbourne, departmental secretary, Anthropology Department, University of Tennessee, Knoxville, for her aid in this revision.

William M. Bass
1979

PREFACE TO THE THIRD EDITION

There has been a tremendous growth in the field of skeletal biology since this text was first published in 1971. In the second edition, I summarized revisions in a separate chapter. In the third edition we have incorporated the information in that chapter within the text at the appropriate locations and have added extensive new material. It should be obvious that the basic anatomy of the bones and general anthropometric measurements have not changed; but the amount of skeletal research, especially in discriminant function analyses, has increased dramatically in the last ten years. This edition contains new data in almost every section, and I have been careful to point out the reference populations that were studied to develop the various discriminant formulae.

William M. Bass
1987

EDITOR'S NOTE

First, I would like to express my gratitude to William M. Bass and Michael J. O'Brien for affording me the opportunity to work together with them in the preparation of the third edition. Numerous other people also were involved in the preparation of the manuscript, and I offer my sincere thanks to each of them. Gregory L. Fox aided me in incorporating Bass' changes, and Thomas D. Holland drafted figures 18, 60, 66, 74, 77, 88, 93, 94, 97, 101, 119, 121, 138, 141, 148, 152, and 156, designed the new cover, and proofed the manuscript for technical accuracy. Teresita Majewski oversaw production, and together with O'Brien proofed and copyedited the manuscript. Holland oversaw the indexing, and Christopher Pulliam helped proof the manuscript and prepare the references. Brian Price also aided with the references and retyped portions of the manuscript. Rosemary Wyatt oversaw composition of the final product.

Michael K. Trimble
University of Missouri
Columbia, Mo.
1987

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INTRODUCTION

WHY STUDY BONES?

Often the question is asked "Why study bones?" A few of the more obvious reasons are listed below.

1. They constitute the evidence for the study of fossil man.
2. They are the basis of racial classification in prehistory.
3. They are the means of biological comparison of prehistoric peoples with the present living descendants.
4. They bear witness to burial patterns and thus give evidence for the culture and world view of the people studied.
5. They form the major source of information on ancient diseases and often give clues as to the causes of death.
6. Their identification often helps solve forensic cases.

Bones are the framework of the vertebrate body and thus contain much information about man's adaptive mechanisms to his environment. The study of evolution essentially would be impossible if bones were eliminated as a source of data. In summary, the answer is that bones often survive the process of decay and provide the main evidence for the human form after death. Skeletal evidence also has the potential to provide information on prehistoric customs and diseases.

BASIC TERMS AND ORIENTATION OF THE BODY

The exact meaning of certain fundamental terms used in anatomy must be understood and kept in mind (see Figure 1). Note that the terms can apply to both two-legged and four-legged animals. The most basic terms are listed below; a more comprehensive list is given in Appendix I.

A. Anatomical Position or Standard Erect Position: standing with the feet forward and the hands at the sides with the palms forward. In this position no long bones are crossed. When the back of the hand is turned forward the radius and the ulna in the lower arm are crossed, with the radius being the outside (lateral) bone at the elbow and the inside (medial) bone at the wrist.

   Always orient the bone you are studying as it is positioned in your body.

   When you are determining the side from which a bone came, the bone always will be from the same side as it is in your body. With the body in

the Standard Erect Position there are three fundamental planes or sections (see Figure 1).

1. Sagittal or midsagittal—that which divides the body into right and left halves.
2. Frontal or coronal—that which divides the body into front and rear portions.
3. Transverse or horizontal—any place at right angles to 1 and 2.

B. Principal directions for parts of the:

1. Body

    Front—ventral or anterior
    Rear—dorsal or posterior
    Upper—cranial or superior
    Lower—caudal or inferior
    Medial—toward the midline
    Lateral—away from the midline

2. Limbs

    Proximal—that portion or end nearest the trunk or head
    Distal—that portion or end farthest from the trunk or head

C. Skeleton (the solid framework of the body) is composed of:

1. Bone. (Ligaments unite the bones in the living.) When bones come together they are said to articulate.
2. Cartilage—tissue covering the surfaces where bones articulate.

D. Four classes of bones:

1. Long bones—main components of limbs; in part sustain weight, and with muscles attached to them form a system of levers for movement.
2. Short bones—metacarpals of hands, metatarsals of feet, and phalanges of hands and feet; found where compactness, elasticity, and limited motion are required.
3. Flat bones—cranial bones, innominates, and scapulae; offer protection and provide wide areas for muscle attachment.
4. Irregular bones—vertebra, carpal (hand) and tarsal (foot) bones, and many of the cranial bones; often very complex and with peculiar forms for the functions they perform.

The total number of bones in the adult skeleton usually is stated to be 206 (Figure 2); however, variations may occur as noted in Table 1.

There usually are 806 centers of ossification in the growing skeleton, but by maturity these centers have united to form the 206 bones of the adult. The surface contour of bone presents irregularities in the shape of eminences and depressions such as:

Name	Description	Bone	Anatomical area
Crest	a ridge, especially one surmounting a bone or its border	innominate radius	iliac crest interosseous crest
Spine	a sharp prominence or slender process of bone	innominate	anterior superior iliac spine
Process	a slender projecting point	vertebra	spinous process
Tubercle	a small tuberosity	skull	external occipital protuberance
Groove	a shallow linear depression	innominate	obturator groove

TABLE 1.

Bones of the Adult Skeleton

Bone	Number
Cranial	
Single	
Frontal	1
Occipital	1
Sphenoid	1
Mandible	1
Ethmoid	1
Vomer	1
Hyoid	1
Total	7
Paired	
Parietal	2
Temporal	2
Maxilla	2
Nasal	2
Zygomatic (malar or cheek)	2
Lacrimal	2
Palate	2
Inferior nasal concha	2
Malleus (ear)	2
Incus (ear)	2
Stapes (ear)	2
Total	22
Postcranial	
Single	
Cervical vertebrae	7
Thoracic vertebrae	12[a]
Lumbar vertebrae	5
Sacrum	1
Coccyx	1[b]
Sternum	1[c]

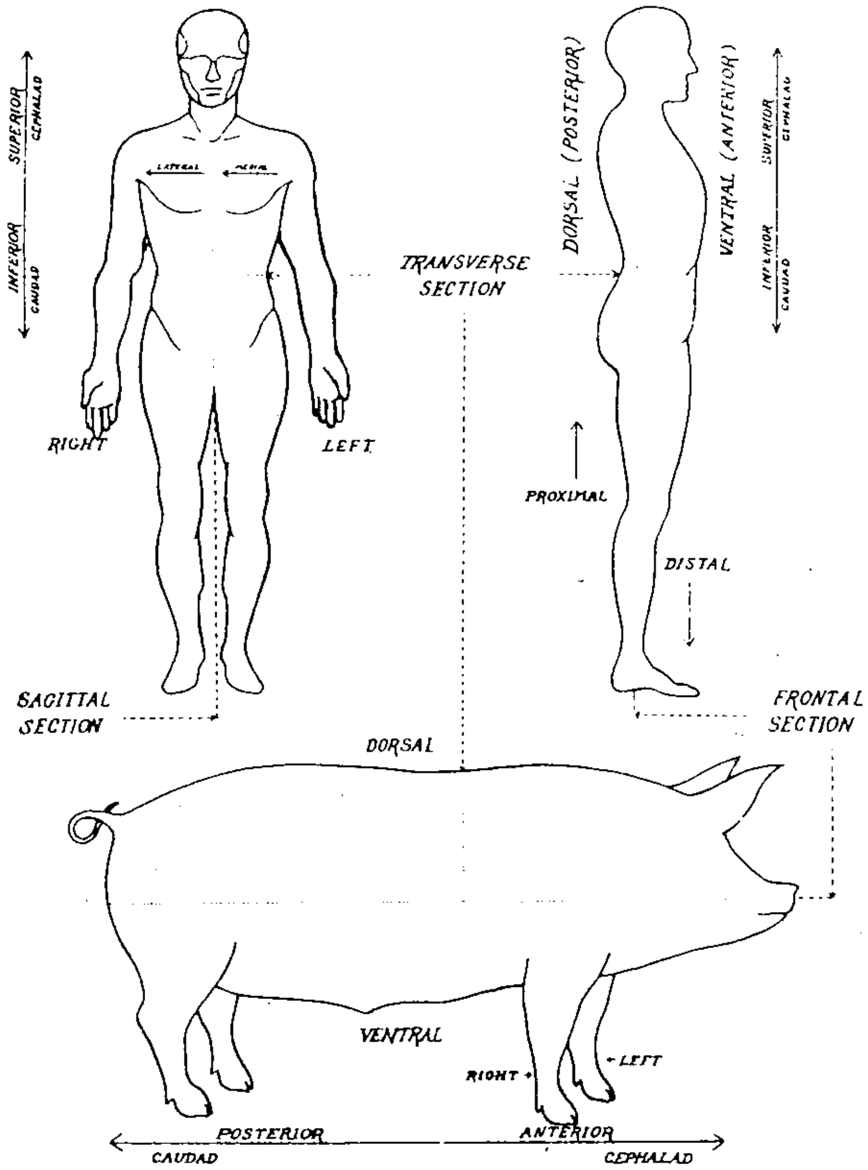


Figure 1. Standard anatomical orientation of the body.

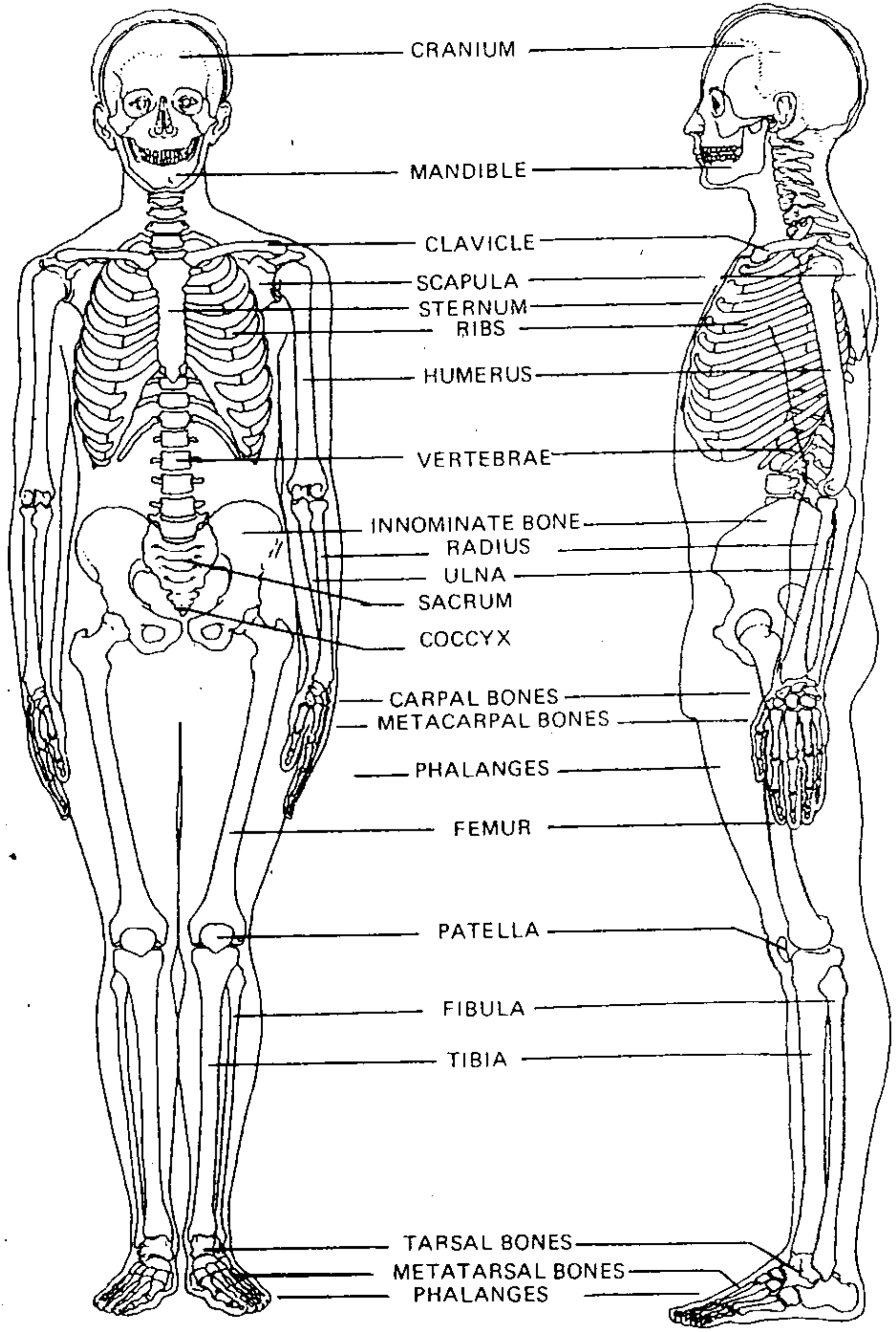


Figure 2. General elements in the human skeleton.

TABLE 1. (Continued)

Bones of the Adult Skeleton

Bone	Number
Paired (upper extremities)	
Scapula	2
Clavicle	2
Ribs	24[d]
Humerus	2
Radius	2
Ulna	2
Carpus	16
Metacarpus	10
Phalanges	28
Total	88
Paired (lower extremities)	
Innominate	2
Femur	2
Patella	2
Tibia	2
Fibula	2
Tarsus	14
Metatarsus	10
Phalanges	28
Total	62
Total	206

[a]Can be 13, see p. 101.
[b]Can have several segments, see p. 105.
[c]Can be 3 or more parts, see p. 109.
[d]Variable, see p. 131.

WHICH BONE IS IT?
STEPS TO FOLLOW IN IDENTIFYING BONES

The student's first encounter with the 206 bones of the human skeleton is often a bewildering experience. Which bone is it? How do I start? What should I look for? These are some of the questions asked by the untrained observer. The best procedure is to follow a logical process of elimination. The following steps are suggested for identification of bones from the human skeleton. (For a key on how to identify bones from mammalian skeletons see Cornwall 1956.)

When faced with the task of determining which bones you are looking for, first decide whether the bone is from a subadult or adult individual

and then proceed with the following steps. (For further information on subadult age estimation see pages 13–15.)

Step 1.

Is it cranial or postcranial (i.e., bones behind the skull in the quadrupedal position)?

Cranial bones are thin, flat, or irregular in shape. Bones from the cranial vault will have serrated edges (sutures); may contain sinuses (sinuses occur in the frontal, maxilla, zygomatic, and sphenoid); and are the only bones in which teeth or tooth sockets occur. If it is a cranial bone the information in Chapter 2 will aid in determination of the exact bone.

Step 2.

If it is postcranial, is it one of the following?

a. Long bone:
    6 paired tubular bones, 3 in each limb
        Arm—humerus, radius, and ulna
        Leg—femur, tibia, and fibula
    A long bone has a tubular shaft and an articular area at each end. Long bones are large compared with other bones of the human body. (The femur is the largest and the radius is the smallest long bone.)
b. Short bone:
    5 metacarpals and 14 phalanges in each hand
    5 metatarsals and 14 phalanges in each foot
    2 clavicles
    Short bones resemble long bones in that they have tubular shafts and usually have articular areas at both ends (a terminal phalanx, however, does not have an articular surface at the distal end).
c. Flat bone (may apply to some cranial bones):
    2 hip bones
    2 scapulae
    24 ribs
    1 sternum
    Flat bones have large surface areas (for muscle attachments) and usually are thin. They have irregularly placed articular surfaces.
d. Irregular bones (may apply to some cranial bones):
    33 bones of the vertebral column
    8 carpal bones
    7 tarsal bones
    2 patellae
    Irregular bones have special shapes for the functions they perform but they usually are thick and short in length. The patella is a sesamoid.

When working with subadult skeletal remains the various bones can resemble any of the four classes above, depending on the age of the

individual. For example, to the untrained eye the femur of an infant who died at birth or soon after may resemble a short bone or the bone of a small mammal. Great care should be taken when dealing with subadult bones (bones in which the epiphyses have not attached). Additional information is presented on each bone in succeeding chapters.

CARE AND TREATMENT OF BONES AND OSTEOMETRIC EQUIPMENT

Human skeletal materials used in physical anthropology laboratories generally are obtained from medical supply houses, dissecting rooms, or archaeological sites. Skeletal remains purchased from medical supply houses are expensive, those obtained from dissecting rooms may include parts that have been sectioned, and those from archaeological sites may be incomplete or poorly preserved. In any case, the material should be treated with care and respect at all times.

In this connection the works of J. W. Powell, the founder of the Bureau of American Ethnology, may be recalled:

> These materials constitute something more than a record of quaint customs and abhorrent rites in which morbid curiosity may revel. In them we find the evidences of traits of character and lines of thought that yet exist and profoundly influence civilization. Passions in the highest culture deemed most sacred—the love of husband and wife, parent and child, and kith and kin, tempering, beautifying, and purifying social life and culminating at death, have their origin far back in the early history of the race and leaven the society of savagery and civilization alike. At either end of the line bereavement by death tears the heart and mortuary customs are symbols of mourning. The mystery which broods over the abbey where lie bones of king and bishop, gathers over the ossuary where lie the bones of chief and shaman; for the same longing to solve the mysteries of life and death, the same yearning for a future life, the same awe of powers more than human, exist alike in the mind of the savage and the sage (Powell 1881:XXVI–XXVII).

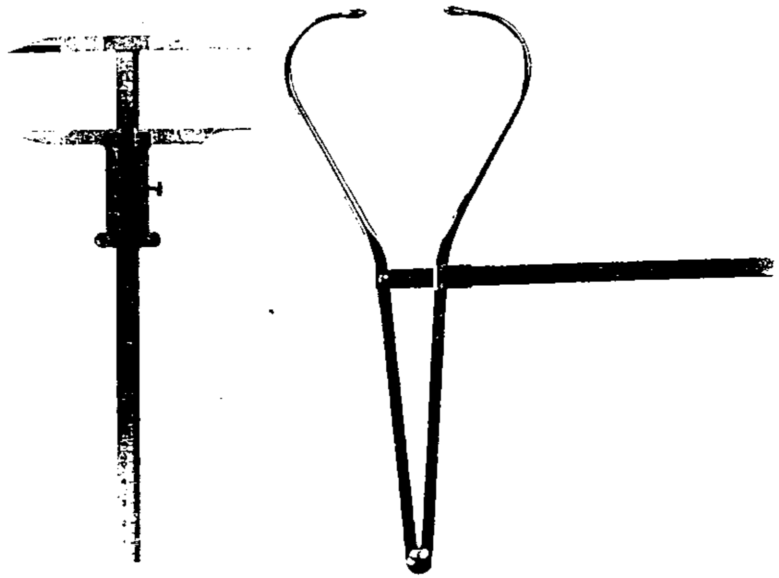
The materials that you will be handling may be studied by many people for years to come and are much like books in a library. Because of the continual development and refinement of scientific techniques, new and possibly significant information can be obtained from previously studied skeletal material. Therefore, care always should be exercised in the handling of skeletal material to preserve it for possible future study.

The proper way to carry or hold a skull is with both hands. The only opening into which fingers safely can be inserted is the foramen magnum—the large opening in the base of the skull. Other openings such as the eye orbits are composed of fragile bones that are destroyed easily by improper handling.

The most common instruments used to measure skeletal material are:

A. The sliding caliper—used for certain cranial measurements in the facial region or on the mandible (Figure 3a). When the reference points for a measurement are relatively close together and the contours of the skull do not interfere with the process of measuring, the sliding caliper generally is the best choice of instrument.

B. The hinge or spreading caliper—devised to enable one to measure points on the skull in which a straight-line-measuring device is not suitable (Figure 3b).



a b

Figure 3. Anthropometric measuring devices: a, sliding caliper; b, hinge (spreading) caliper.

C. The osteometric board—the easiest, most accurate instrument for measuring long bones and other large postcranial bones (Figure 4).

These instruments are very expensive because they must be made with great precision. Common sense should dictate the procedure for handling them.

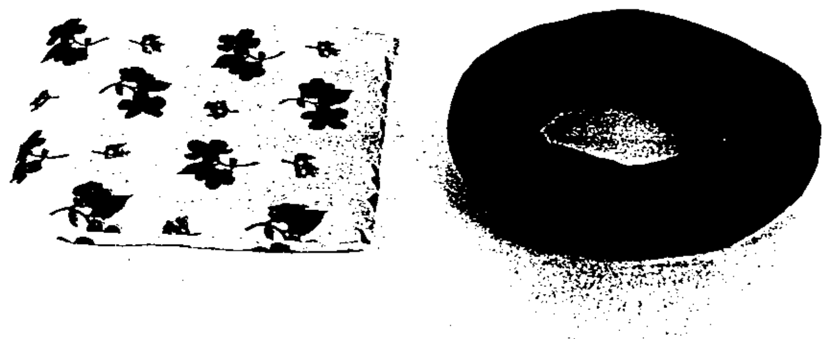
A bean bag or donut ring should be used to support a skull on a flat surface (Figure 5). A serviceable bag can be made by sewing together two 6-x-6-inch pieces of cloth or by folding and sewing one 6-x-12-inch strip (Figure 5a). Before completing the sewing, 1 cup of dry beans should be

Figure 4. An osteometric board.

put into the bag. The beans should be loose enough in the bag so that when the skull is placed thereon the beans will spread out and hold the skull in the desired position.

A donut ring serves the same purpose as a bean bag but is more difficult to construct (Figure 5b). It should be approximately 6 inches in diameter, with the hole from 2½ to 3 inches in diameter. The ring is filled with old rags or stockings to form a soft, firm base for the skull.

Two anthropometric instruments not as commonly used as those discussed above, but which are extremely useful for taking more difficult measurements are:

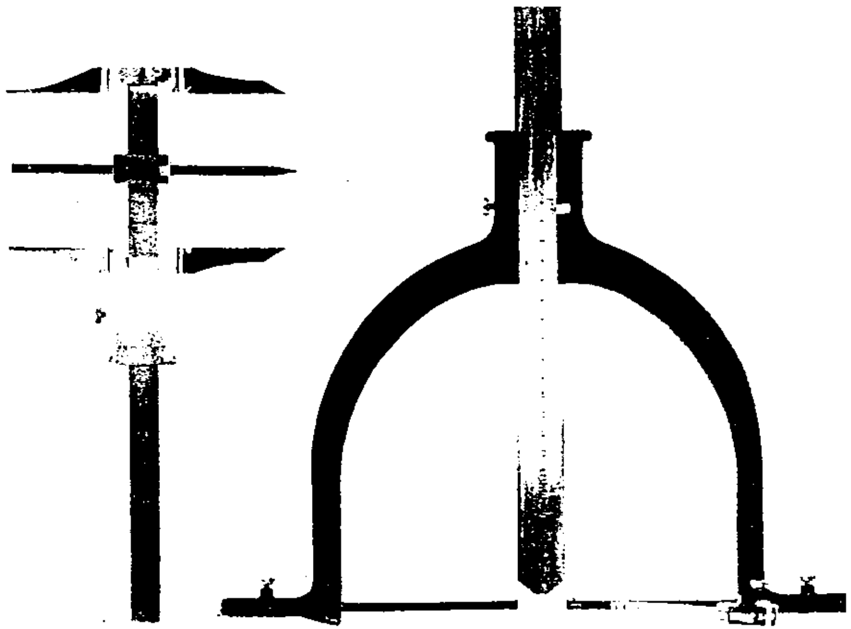


a b

Figure 5. Cranial rests: a, bean bag; b, donut ring.

D. The coordinate caliper—a sliding caliper with a coordinate attachment for measuring depths below or elevations above two points (Figure 6a). The sharp ends of the sliding caliper are placed on two anatomical landmarks, and the coordinate attachment is moved so that its sharp point touches the area to be measured. Depths or elevations are read from the millimeter scale on the coordinate attachment.

E. The head spanner (a Western Reserve Model designed by Dr. T. Wingate Todd and illustrated in Figure 6b)—used to take measurements along the midsagittal plane with reference to porion. The ear attachments are placed in both ear holes (external auditory meatus) at porion, and the calibrated measuring rod records distance from the line connecting the two rods. Auricular height can be taken with the use of the attachment to locate orbitale, thus relating the skull to the Frankfort Horizontal or Plane.



a b

Figure 6. Two anthropometric measuring devices: a, coordinate caliper; b, Western Reserve Model Head Spanner.

MEASUREMENT OF THE BONES

Many measurements can be taken on the skull and on the long bones, as well as on many of the irregular bones. The length measurements of the long bones may be used to calculate stature, while certain other measurements may be used to determine sex and race. In general, the measurements and indices presented in this manual are those most commonly used by physical anthropologists and for which comparative data are available. Following the descriptions of each bone is a list of basic measurements.

Age Estimation

Entire books have been and could be written exclusively on age estimation from the skeleton (e.g., Stewart and Trotter 1954). It is not the intent here to be exhaustive, but rather to acquaint the student with areas of the body used to determine the age of an individual at death and to present basic references where more detailed information can be found.

When we say "age estimation" we do not mean how long the individual has been dead. It is difficult, if not impossible, in most cases (without a chemical analysis of the skeleton) to determine how long an individual has been dead. There are various means of estimating time elapsed since death, most of which are derived from related fields (e.g., stratification from archaeology and radiocarbon dating from physics). The main concern here, however, is determining the age of an individual at death. To do this we ask: What biological changes occur in the skeleton during life that allow us to estimate the age at death with a reasonable degree of accuracy?

The biological age of a skeleton can be determined with varying degrees of success, depending on the period of life reached. At the stage when the teeth are erupting and the epiphyses uniting, age often can be judged quite precisely. After growth has stopped and the permanent dentition has erupted—that is onwards from about 25 to 30 years—the estimation of age depends almost entirely on degenerative changes.

One of the major factors students should be aware of is human variability. All children crawl before they walk, and walk before they run, but not all children do these at the same time. One child may walk at 9 months, whereas another may not walk until 18 months. This is to illustrate only that people mature at different rates. The same sort of variability also exists in the formation of teeth and bones as Stewart (1963) has pointed out.

Historically, we do not find reliable data on age indicators until after World War I. During the 1920s, T. Wingate Todd and others at Case Western Reserve University began studying topics such as epiphyseal union in documented skeletons from the dissecting rooms. Their objective was to establish general biological rules concerning sequential changes in the skeleton during life.

A decade later, Rudolph Kronfeld of the Loyola University Dental School summarized the histologic and roentgenographic data on several aspects of tooth formation for both the deciduous and permanent dentitions (Kronfeld 1935).

By the 1950s anthropologists increasingly were becoming aware of the great range of human variation and the need for more refined techniques of biological aging.

However, a major problem exists in obtaining adequate samples of documented skeletons, i.e., skeletons of known sex, race, and age at death. Since documented skeletal populations usually come from anatomical dissecting rooms, they tend to be heavily weighted toward individuals in the older age range and from the lower socio-economic levels. A breakthrough in this "age-old" problem was achieved—at least for males—by McKern and Stewart (1957) in their study of skeletal-age changes in young Americans killed in the Korean War. Garn and his associates also contributed valuable data on variability in tooth formation and its relation to other maturity indicators as seen in successive X-rays taken in life (Lewis and Garn 1960).

Although Krogman had written many short articles on what skeletons have to tell, it was not until 1962 that he brought much of the information together in a textbook entitled *The Human Skeleton in Forensic Medicine* (Krogman 1962).

Since the 1960s, techniques for determining skeletal or biological age have become much more refined. For example, Kerley (1965) published one the first microscopic techniques for determining age of human bone. It is my belief that physical anthropology is on the verge of major achievements in the area of skeletal aging. What follows in this manual is only an outline of developments to date designed to acquaint the student with basic techniques. To approach this problem, we should first determine whether the bones on which we are to estimate age are from a subadult or adult skeleton.

Subadult Age Estimation

There are a number of criteria that can be used:

1. Tooth eruption
2. Epiphyseal closure
3. Length of long bones without epiphyses

Tooth eruption—The following are *very general* age categories; more specific information can be gained from Figure 7 and from the references.

Birth—usually no teeth erupted

6 mo.—first deciduous teeth usually begin to appear (lower central incisors first)
24 mo.—usually all 20 deciduous teeth have erupted
2–6 yrs.—ossification of the roots of the teeth proceeds; the teeth do not get any larger

As the child grows and the mandible and maxilla get larger, spaces begin to form between the deciduous teeth.

6 yrs.—first permanent teeth (6-year molars) appear
6½ yrs.—beginning of loss of deciduous teeth (the central incisors being lost first)
6½–11 yrs.—period of loss of deciduous teeth and replacement by permanent teeth
12 yrs.—second permanent molars (12-year molars) appear
18 yrs.—the third molars (wisdom teeth) possibly appear. This is a genetically unstable tooth and may never appear, or may erupt beyond age 18.

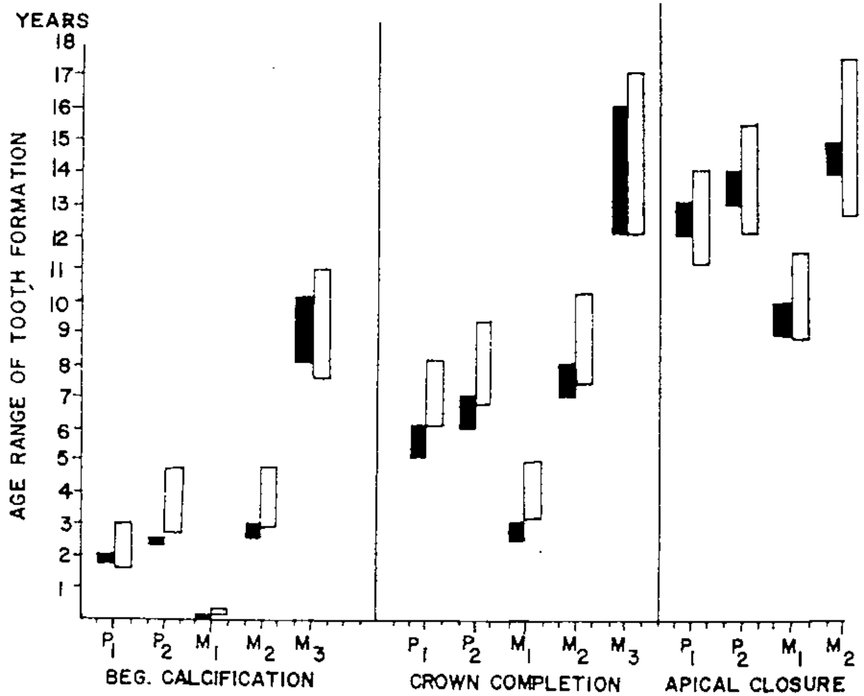


Figure 7. Variations in tooth formation. Comparison between age ranges of Kronfeld (1935) and 5th–95th-percentile limits of Garn *et al.* (1959) for beginning of calcification, crown completion, and apical closure of P_1–M_3. Solid bars = Kronfeld; open bars = Garn *et al.* (1959) (from Stewart 1963:Figure 1).

Few people stop to realize that the average newborn baby is approximately 20 inches long and that during the first 18 years of life, the individual more than triples in length—if a male, to about 5½ to 6½ feet, and if a female, to about 5 to 5½ feet. The first 16 to 18 years are a period of very rapid growth (Figure 8).

The bones of the human skeleton develop from a number of centers of ossification. It has been estimated that at about the eleventh prenatal week there are approximately 806 centers of bone growth in the human skeleton. As the skeleton grows, these centers unite so that at birth there are some 450 centers and by adulthood these have united to form the 206 bones of the skeleton.

A typical long bone will have three centers of ossification, one primary and two secondary.

Primary:
Diaphysis or shaft—the mid-portion of the bone
Secondary:
Two epiphyses or ends—the end portions of the bone

The layer of cartilage between an ossifying epiphysis and a diaphysis is known as an epiphyseal plate or disk. The metaphysis is the area of the diaphysis adjacent to the plate and is the region where growth in length takes place (Figure 9).

All long bones (as well as metacarpals, metatarsals, and phalanges) have an epiphysis at one end, and most have them at both ends. An epiphysis probably functions as a protective cap to the metaphysis or the active growing region of the bone (Grant 1952). Long bones with epiphyses at both ends include:

Humerus
Radius
Ulna
Femur
Tibia
Fibula

The clavicle, first and second metacarpals, and the first metatarsal occasionally have epiphyses at both ends.

Growth of Long Bones

Long bones do not grow at the same rate at both ends. In a long bone with two epiphyses, the first epiphysis to start ossification is at the end making the greatest contribution to growth in length. It is, however, the last to fuse with the diaphysis. Growth stops when the epiphyses unite with the diaphysis. It is not understood clearly why the epiphyses unite when they do, but it is involved with the endocrine system. Abnormalities can and do occur. Premature union of the epiphyses results in a dwarfed

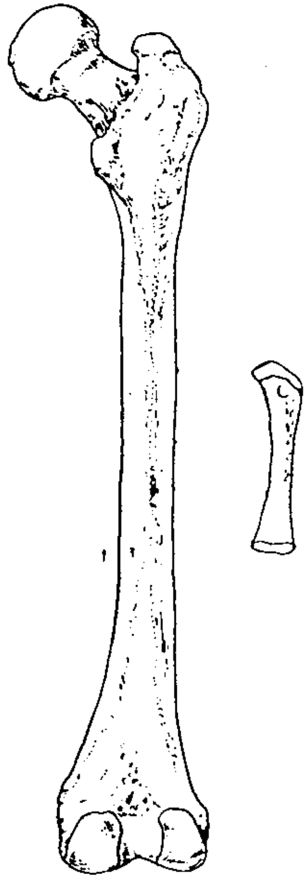


Figure 8. Comparison of an adult femur with that of a neonate (right bones depicted).

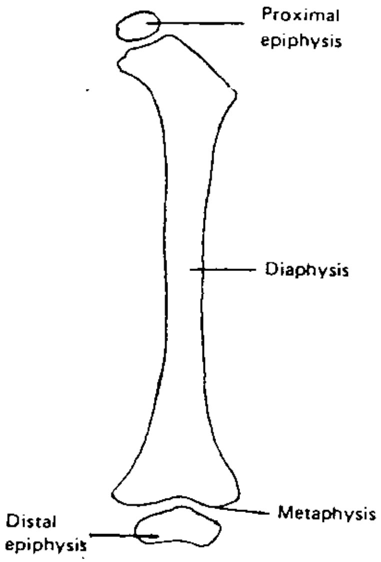


Figure 9. Ossification centers in a subadult femur.

condition known as achondroplasia. Failure of union at the proper time results in giantism; however, this is seldom seen today, since epiphyseal union can be stimulated by hormone therapy.

Ossification begins earlier in females, and the epiphyses unite earlier as well, normally some two to three years sooner. This leads to a shorter period of growth in females and accounts for their smaller adult size when compared with males.

Epiphyses ossify from a single center, with the cartilaginous epiphyseal disk being replaced by bone. Following complete ossification of the cartilaginous epiphyseal disk, union of the epiphysis and the diaphysis occurs.

All long-bone shafts are ossified at birth, as are many parts of the rest of the skeleton. Krogman (1962:19–21) states that "at birth only six epiphyseal centers are present: head of humerus (proximal); condyle of femur (distal); condyle of tibia (proximal); talus, calcaneous and cuboid (tarsal bones in foot). The first three will unite with their respective shafts; the second three (as is true of all carpal bones of the hand and tarsal bones of the foot) will remain as discrete bones throughout life."

The early stages of the ossification of an epiphysis may be difficult to detect in skeletal remains. The epiphysis is then often no more than an amorphous lump. Because it usually is rounded and lacking in morphological detail, it may be mistaken for a pebble by the untrained excavator of burials. As it gets larger it begins to take on its characteristic adult shape, and with more time morphological details can be identified. However, great care always must be taken in the recovery and identification of epiphyses.

Epiphyseal union—each long bone of the body is made up of:

A diaphysis or shaft.

Two epiphyses or ends of bones (one at each end). Some bones have additional epiphyses (as greater and lesser trochanters of the femur).

A look at Chapter 2 of Krogman (1962) will show the reader that many lists of ages for epiphyseal unions are available. Tables 2 and 3 are from McKern and Stewart (1957) and represent data on epiphyseal union in males. In these tables, stages refer to:

0—open suture (no union)
1—one-quarter united or fused
2—one-half united or fused
3—three-quarters united or fused
4—completely united or fused

For additional discussion, refer to Greulich and Pyle (1959), Krogman (1962), and McKern and Stewart (1957).

Tooth wear—in modern populations, tooth wear will not offer much help in aging, and even in prehistoric populations it is of limited value. Much research needs to be conducted on dental attrition and its correlation with different foods and food preparation techniques.

Wear will not be marked to the same degree on all molars since they erupt at different ages. In other words the first molars are exposed to about 12 more years of mastication than the third molars and about 6 years more than the second molars. When an age determination is attempted, that difference needs to be kept in mind. Again, it also is important to remember that all populations do not have the same rate of attrition, and therefore the criteria for determining age from tooth wear in one population do not necessarily apply to another population. Unfortunately, all the dentitions within a population do not wear at the same rate due to

TABLE 2.

The Age Distribution for Stages of Union for the Long-Bone Epiphyses of Group II[a]

		Upper extremity														
		Humerus (proximal) stages					Radius (distal) stages					Ulna (distal) stages				
Age	N	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
17–18	55	14[b]	5	25	35	21	22	3	14	32	29	29	1	11	24	35
19	52	5	2	10	58	25	7	-	5	48	40	7	-	5	32	56
20	45	2	2	4	40	52	4	-	2	24	70	4	2	-	24	70
21	37			2	27	71				19	81				10	90
22	24				12	88				12	88				8	92
23	26				4	96					100					100
24+	136				-	100										
Total	375															

		Lower extremity														
		Femur (distal) stages					Tibia (proximal) stages					Fibula (proximal) stages				
Age	N	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
17–18	55	16	2	3	18	61	2	2	7	23	66	14	-	3	12	71
19	52	4	-	1	9	86	1	-	1	17	81	4	-	6	4	86
20	45			2	9	89				13	87			2	-	98
21	37				8	92				5	95				5	95
22	24					100				4	96					100
23	26										100					
24+	136															
Total	375															

[a]From McKern and Stewart (1957:Table 21).
[b]All figures represent percentages.

individual differences in diet and tooth structure. This severely limits the accuracy of age determination by this method.

Development of osteoarthritis—following the period of union of the epiphyses from the mid-20s onward, degenerative changes can be noted on and around the joint surfaces of many skeletons. Stewart (1958) has been interested in vertebral osteoarthritis as an aid in skeletal-age identification. He studied the osteophytes (lipping) indicative of advancing age on the superior and inferior borders of each vertebral centrum and assigned a subjective rating scale running from 0 (no lipping) to 4+ (maximum lipping).

TABLE 3.

Epiphysis on the Iliac Crest: Age Distribution of Stages of Union[a]

		Stages of Union				
Age	N	0	1	2	3	4
17	10	40[b]	10	10	40	-
18	45	18	16	26	20	20
19	52	5	4	27	28	36
20	45	2	6	4	24	64
21	37	-	5	8	13	74
22	24	-	-	4	4	92
23	26	-	-	-	-	100
Total	239					

[a]From McKern and Stewart (1957:Table 22).
[b]All figures represent percentages.

Stewart concluded that: (a) between the ages of 20 and 30 lipping develops rather slowly; (b) between 30 and 40 lipping intensifies; (c) between 40 and 50 lipping intensifies, especially in the lumbar region; and (d) beyond the age of 50, lipping becomes quite pronounced. His data are displayed graphically in figures 10–12.

Sex Estimation

When a skeleton is discovered during excavation or observed in the laboratory, one of the first questions asked is: "Is it male or female?" Many criteria for estimating the sex of a skeleton have been published in the anthropological and anatomical literature. As stated earlier, it is the intent here to present only a few basic criteria for sexing bones and to list references where additional information can be obtained.

The questions still arises as to whether subadult skeletal material can be accurately sexed, but the consensus is that any determination is little better than a guess. The secondary characteristics do not manifest themselves until puberty; thus it is impossible to judge the remains of children and adolescents because the means available relate to adult traits. Most of the techniques employed to determine the sex of subadult bones depend on X-rays taken in life. These techniques seldom apply to dry bone. Additional information on sex determination of subadult remains can be found in Boucher (1955, 1957), Hunt and Gleiser (1955), Imrie and Wyburn (1958), and Reynolds (1945, 1947).

In general the sex differences in the adult long bones are a matter of size, typical male bones being longer and larger (more massive) than typical female bones (Krogman 1962:143). In addition, to simplify observa-

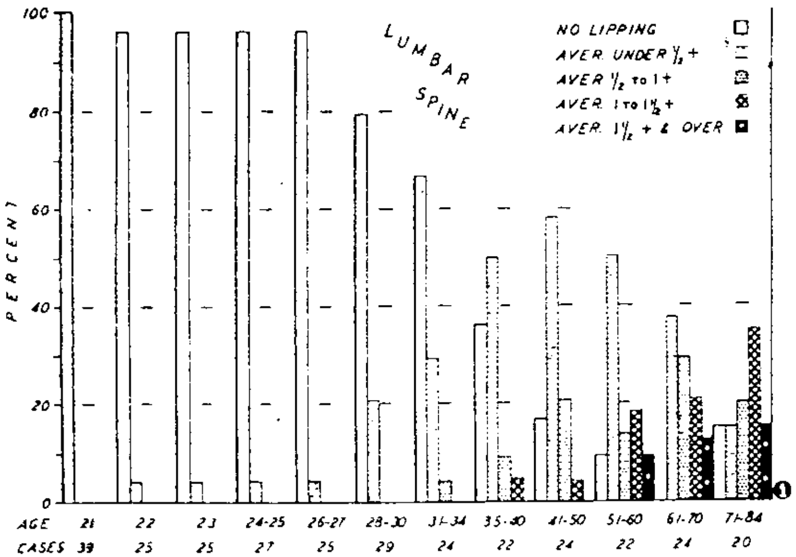


Figure 10. Distribution of 5 categories of osteophytosis in 306 lumbar spines of white American males ranging in age from 21 to 84 (from Stewart 1958:Figure 1). Permission for reproduction granted by T. D. Stewart.

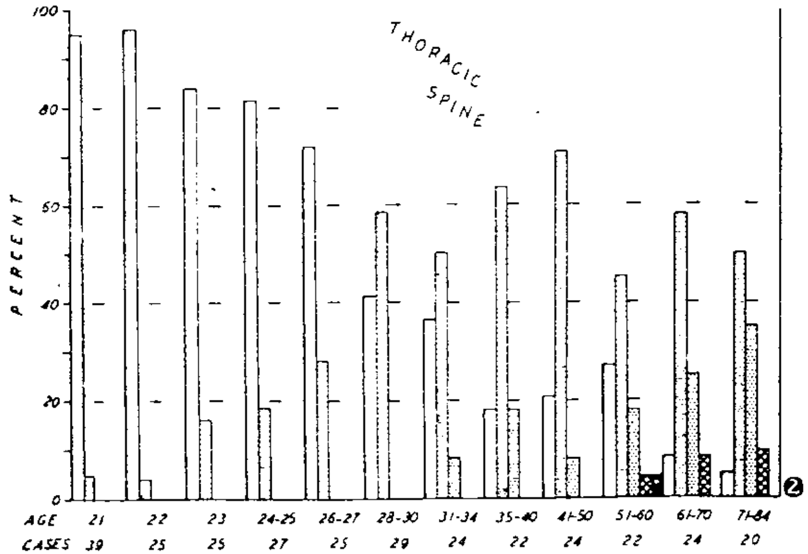


Figure 11. Distribution of 5 categories of osteophytosis in 306 thoracic spines of white American males ranging in age from 21 to 84 years (see Figure 10 for categories), (from Stewart 1958:Figure 2). Permission for reproduction granted by T. D. Stewart.

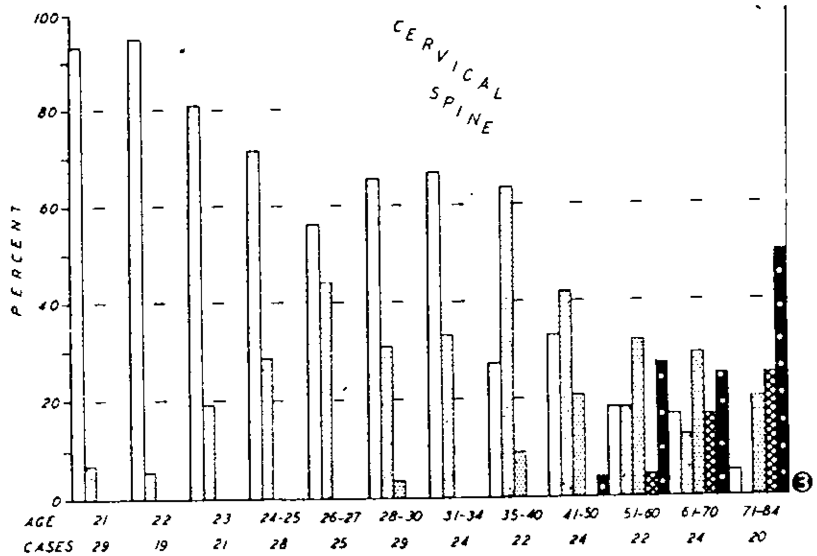


Figure 12. Distribution of 5 categories of osteophytosis in 287 cervical spines of white American males ranging in age from 21 to 84 years (see Figure 10 for categories), (from Stewart 1958:Figure 3). Permission for reproduction granted by T. D. Stewart.

tion of size, measurements of the maximum diameter of the head of the humerus and of the femur are especially useful in sex estimation.

Femur—Krogman (1962) gives a summary of data on measurements of the various long bones. Pearson (1917–19) gives the following information for maximum diameter in mm of the head of the femur:

Female	Probably female	Sex indeterminate	Probably male	Male
X–41.5	41.5–43.5	43.5–44.5	44.5–45.5	45.5–X

Dwight (1905:22) gives the average maximum diameter of the femur head as 49.68 mm for males and 43.84 mm for females.

Humerus—Dwight (1905:22) also provides data on the diameter of the humeral head in mm.

	Vertical	Transverse
Male	48.76	44.66
Female	42.67	36.98

Stature Estimation

The estimation of living stature from the length of the long bones has long been of interest to the physical anthropologist. Some of the earliest scientific efforts along this line were undertaken in the latter half of the 1800s on the basis of simple ratios.

It was not until late in the nineteenth century, with the development of mathematical regression equations, that Karl Pearson (1898) published a series of formulae for estimating living stature from the lengths of dried long bones. Lists of tables and formulae from this early work have been published by Krogman (1962). Because the studies of Trotter and Gleser (1952, 1958) are the most reliable, their stature-estimation tables for whites and blacks are reproduced in tables 4–7. (Stature estimates are given in both centimeters and inches.)

TABLE 4.

Expected Maximum Stature[a] from Long-Bone Lengths for American White Males[b]

Hum.	Rad.	Ulna	Stature		Fem.	Tib.	Fib.	Fem. + Tib.
mm	mm	mm	cm	in[c]	mm	mm	mm	mm
265	193	211	152	59^{7}	381	291	299	685
268	196	213	153	60^{2}	385	295	303	693
271	198	216	154	60^{5}	389	299	307	701
275	201	219	155	61	393	303	311	708
278	204	222	156	61^{3}	398	307	314	716
281	206	224	157	61^{7}	402	311	318	723
284	209	227	158	62^{2}	406	315	322	731
288	212	230	159	62^{5}	410	319	326	738
291	214	232	160	63	414	323	329	746
294	217	235	161	63^{3}	419	327	333	753
297	220	238	162	63^{6}	423	331	337	761
301	222	240	163	64^{1}	427	335	340	769
304	225	243	164	64^{5}	431	339	344	776
307	228	246	165	65	435	343	348	784
310	230	249	166	65^{3}	440	347	352	791
314	233	251	167	65^{6}	444	351	355	799
317	235	254	168	66^{1}	448	355	359	806
320	238	257	169	66^{4}	452	359	363	814
323	241	259	170	66^{7}	456	363	367	821
327	243	262	171	67^{3}	461	367	370	829
330	246	265	172	67^{6}	465	371	374	837
333	249	267	173	68^{1}	469	375	378	844
336	251	270	174	68^{4}	473	379	381	852
339	254	273	175	68^{7}	477	383	385	859
343	257	276	176	69^{2}	482	386	389	867
346	259	278	177	69^{5}	486	390	393	874

TABLE 4. (Continued)

Expected Maximum Stature[a] from Long-Bone Lengths for American White Males[b]

Hum.	Rad.	Ulna	Stature		Fem.	Tib.	Fib.	Fem. + Tib.
mm	mm	mm	cm	in[c]	mm	mm	mm	mm
349	262	281	178	70^{1}	490	394	396	882
352	265	284	179	70^{4}	494	398	400	889
356	267	286	180	70^{7}	498	402	404	897
359	270	289	181	71^{2}	503	406	408	905
362	272	292	182	71^{5}	507	410	411	912
365	275	294	183	72	511	414	415	920
369	278	297	184	72^{4}	515	418	419	927
372	280	300	185	72^{7}	519	422	422	935
375	283	303	186	73^{2}	524	426	426	942
378	286	305	187	73^{5}	528	430	430	950
382	288	308	188	74	532	434	434	957
385	291	311	189	74^{3}	536	438	437	965
388	294	313	190	74^{6}	540	442	441	973
391	296	316	191	75^{2}	545	446	445	980
395	299	319	192	75^{5}	549	450	449	988
398	302	321	193	76	553	454	452	995
401	304	324	194	76^{3}	557	458	456	1003
404	307	327	195	76^{6}	561	462	460	1010
408	309	330	196	77^{1}	566	466	463	1018
411	312	332	197	77^{4}	570	470	467	1026
414	315	335	198	78	574	474	471	1033

[a]The expected maximum stature should be reduced by the amount of .06 (age in years −30) cm to obtain expected stature of individuals over 30 years of age.

[b]From Trotter and Gleser (1952:496).

[c]The raised number indicates the numerator of a fraction of an inch expressed in eighths, plus 59^{7} should be read 59 ⅞ inches.

TABLE 5.

Expected Maximum Stature[a] from Long-Bone Lengths for American White Females[b]

Hum.	Rad.	Ulna	Stature		Fem.	Tib.	Fib.	Fem. + Tib.
mm	mm	mm	cm	in[c]	mm	mm	mm	mm
244	179	193	140	55^{1}	348	271	274	624
247	182	195	141	55^{4}	352	274	278	632
250	184	197	142	55^{7}	356	277	281	639
253	186	200	143	56^{2}	360	281	285	646
256	188	202	144	56^{6}	364	284	288	653
259	190	204	145	57^{1}	368	288	291	660
262	192	207	146	57^{4}	372	291	295	668
265	194	209	147	57^{7}	376	295	298	675
268	196	211	148	58^{2}	380	298	302	682
271	198	214	149	58^{5}	384	302	305	689

TABLE 5. (Continued)

Expected Maximum Stature[a] from Long-Bone Lengths for American White Females[b]

Hum.	Rad.	Ulna	Stature		Fem.	Tib.	Fib.	Fem. - Tib.
mm	*mm*	*mm*	*cm*	*in*[c]	*mm*	*mm*	*mm*	*mm*
274	201	216	150	59	388	305	309	696
277	203	218	151	59^{4}	392	309	312	704
280	205	221	152	59^{7}	396	312	315	711
283	207	223	153	60^{2}	400	315	319	718
286	209	225	154	60^{5}	404	319	322	725
289	211	228	155	61	409	322	326	732
292	213	230	156	61^{3}	413	326	329	740
295	215	232	157	61^{6}	417	329	332	747
298	217	235	158	62^{2}	421	333	336	754
301	220	237	159	62^{5}	425	336	340	761
304	222	239	160	63	429	340	343	768
307	224	242	161	63^{3}	433	343	346	776
310	226	244	162	63^{6}	437	346	349	783
313	228	246	163	64^{1}	441	350	353	790
316	230	249	164	64^{5}	445	353	356	797
319	232	251	165	65	449	357	360	804
322	234	253	166	65^{3}	453	360	363	812
324	236	256	167	65^{6}	457	364	366	819
327	239	258	168	66^{1}	461	367	370	826
330	241	261	169	66^{4}	465	371	373	833
333	243	263	170	66^{7}	469	374	377	840
336	245	265	171	67^{3}	473	377	380	847
339	247	268	172	67^{6}	477	384	384	855
342	249	270	173	68^{1}	481	384	387	862
345	251	272	174	68^{4}	485	388	390	869
348	253	275	175	68^{7}	489	391	394	876
351	255	277	176	69^{2}	494	395	397	883
354	258	279	177	69^{5}	498	398	401	891
357	260	282	178	70^{1}	502	402	404	898
360	262	284	179	70^{4}	506	405	407	905
363	264	286	180	70^{7}	510	409	411	912
366	266	289	181	71^{2}	514	412	414	919
369	268	291	182	71^{5}	518	415	418	927
372	270	293	183	72	522	419	421	934
375	272	296	184	72^{4}	526	422	425	941

[a] The expected maximum stature should be reduced by the amount of .06 (age in years −30) cm to obtain expected stature of individuals over 30 years of age.

[b] From Trotter and Gleser (1952:498).

[c] The raised number indicates the numerator of a fraction of an inch expressed in eighths, thus 55^{1} should be read 55⅛ inches.

TABLE 6.

Expected Maximum Stature[a] from Long-Bone Lengths for American Negro Males[b]

Hum.	Rad.	Ulna	Stature		Fem.	Tib.	Fib.	Fem. + Tib.
mm	*mm*	*mm*	*cm*	*in*[c]	*mm*	*mm*	*mm*	*mm*
276	206	223	152	59^{7}	387	301	303	704
279	209	226	153	60^{2}	391	306	308	713
282	212	229	154	60^{5}	396	310	312	721
285	215	232	155	61	401	315	317	730
288	218	235	156	61^{3}	406	320	321	739
291	221	238	157	61^{6}	410	324	326	747
294	224	242	158	62^{2}	415	329	330	756
297	226	245	159	62^{5}	420	333	335	765
300	229	248	160	63	425	338	339	774
303	232	251	161	63^{3}	430	342	344	782
306	235	254	162	63^{6}	434	347	349	791
310	238	257	163	64^{1}	439	352	353	800
313	241	260	164	64^{5}	444	356	358	808
316	244	263	165	65	449	361	362	817
319	247	266	166	65^{3}	453	365	367	826
322	250	269	167	65^{6}	458	370	371	834
325	253	272	168	66^{1}	463	374	376	843
328	256	275	169	66^{4}	468	379	381	852
331	259	278	170	66^{7}	472	383	385	861
334	262	281	171	67^{3}	477	388	390	869
337	264	284	172	67^{6}	482	393	394	878
340	267	287	173	68^{1}	487	397	399	887
343	270	291	174	68^{5}	491	402	403	895
346	273	294	175	68^{7}	496	406	408	904
349	276	297	176	69^{2}	501	411	413	913
352	279	300	177	69^{5}	506	415	417	921
356	282	303	178	70	510	420	422	930
359	285	306	179	70^{4}	515	425	426	939
362	288	309	180	70^{7}	520	429	431	947
365	291	312	181	71^{2}	525	434	435	956
368	294	315	182	71^{5}	529	438	440	965
371	297	318	183	72	534	443	445	974
374	300	321	184	72^{4}	539	447	449	982
377	302	324	185	72^{7}	544	452	454	991
380	305	327	186	73^{2}	548	456	458	1000
383	308	330	187	73^{5}	553	461	463	1008
386	311	333	188	74	558	466	467	1017
389	314	336	189	74^{3}	563	470	472	1026
392	317	340	190	74^{6}	567	475	476	1034
395	320	343	191	75^{2}	572	479	481	1043
398	323	346	192	75^{5}	577	484	486	1052
401	326	349	193	76	582	488	490	1061
405	329	352	194	76^{3}	586	493	495	1069

TABLE 6. (Continued)

Expected Maximum Stature[a] from Long-Bone Lengths for American Negro Males[b]

Hum.	Rad.	Ulna	Stature		Fem.	Tib.	Fib.	Fem. + Tib.
mm	*mm*	*mm*	*cm*	*in*[c]	*mm*	*mm*	*mm*	*mm*
408	332	355	195	76^{6}	591	498	499	1078
411	335	358	196	77^{1}	596	502	504	1087
414	337	361	197	77^{4}	601	507	508	1095
417	340	364	198	78	605	511	513	1104

[a]The expected maximum stature should be reduced by the amount of .06 (age in years −30) cm to obtain expected stature of individuals over 30 years of age.

[b]From Trotter and Gleser (1952:497).

[c]The raised number indicates the numerator of a fraction of an inch expressed in eighths, thus 59^{7} should be read 59⅞ inches.

TABLE 7.

Expected Maximum Stature[a] from Long-Bone Lengths for American Negro Females[b]

Hum.	Rad.	Ulna	Stature		Fem.	Tib.	Fib.	Fem. + Tib.
mm	*mm*	*mm*	*cm*	*in*[c]	*mm*	*mm*	*mm*	*mm*
245	165	195	140	55^{1}	352	275	278	637
248	169	198	141	55^{4}	356	279	282	645
251	173	201	142	55^{7}	361	283	286	653
254	176	204	143	56^{2}	365	287	290	661
258	180	207	144	56^{5}	369	291	294	669
261	184	210	145	57^{1}	374	295	298	677
264	187	213	146	57^{4}	378	299	302	685
267	191	216	147	57^{7}	383	303	306	693
271	195	219	148	58^{2}	387	308	310	701
274	198	222	149	58^{5}	391	312	314	709
277	202	225	150	59	396	316	318	717
280	205	228	151	59^{4}	400	320	322	724
284	209	231	152	59^{7}	405	324	326	732
287	213	235	153	60^{2}	409	328	330	740
290	216	238	154	60^{5}	413	332	334	748
293	220	241	155	61	418	336	338	756
297	224	244	156	61^{3}	422	340	342	764
300	227	247	157	61^{6}	426	344	346	772
303	231	250	158	62^{2}	431	348	350	780
306	235	253	159	62^{5}	435	352	354	788
310	238	256	160	63	440	357	358	796
313	242	259	161	63^{3}	444	361	362	804
316	245	262	162	63^{6}	448	365	366	812
319	249	265	163	64^{1}	453	369	370	820
322	253	268	164	64^{5}	457	373	374	828

TABLE 7. (Continued)

Expected Maximum Stature[a] from Long-Bone Lengths for American Negro Females[b]

Hum.	Rad.	Ulna	Stature		Fem.	Tib.	Fib.	Fem. + Tib.
mm	*mm*	*mm*	*cm*	*in*[c]	*mm*	*mm*	*mm*	*mm*
326	256	271	165	65	462	377	378	836
329	260	274	166	65^{3}	466	381	382	843
332	264	277	167	65^{6}	470	385	386	851
335	267	280	168	66^{1}	475	389	390	859
339	271	283	169	66^{4}	479	393	394	867
342	275	286	170	66^{7}	484	397	398	875
345	278	289	171	67^{3}	488	401	402	883
348	282	292	172	67^{6}	492	406	406	891
352	285	295	173	68^{1}	497	410	410	899
355	289	298	174	68^{4}	501	414	414	907
358	293	301	175	68^{7}	505	418	418	915
361	296	304	176	69^{2}	510	422	422	923
365	300	307	177	69^{5}	514	426	426	931
368	304	310	178	70^{1}	519	430	430	939
371	307	313	179	70^{4}	523	434	434	947
374	311	316	180	70^{7}	527	438	438	955
378	315	319	181	71^{2}	532	442	442	963
381	318	322	182	71^{5}	536	446	446	970
384	322	325	183	72	541	450	450	978
387	325	328	184	72^{4}	545	454	454	986

[a]The expected maximum stature should be reduced by the amount of .06 (age in years −30)cm to obtain expected stature of individuals over 30 years of age.

[b]From Trotter and Gleser (1952:499).

[c]The raised number indicates the numerator of a fraction of an inch expressed in eighths, thus 55^{1} should be read 55⅛ inches.

Various authors have demonstrated that estimation is complicated by racial differences among population samples. The racial affiliation of the sample must be known, and the appropriate formulae or tables for that racial group must be used to estimate stature. Given these general cautions, the following references are recommended reading on stature estimation (Breitinger 1938; Dupertuis and Hadden 1951; Dwight 1894a; Genovés 1967; Hrdlička 1952; Krogman 1962; Manouvrier 1893; Pearson 1898; Stevensen 1929; Telkkä 1950; and Trotter and Gleser 1952, 1958).

As discussed above, perhaps the most used formula for estimating living stature from skeletal material is that of Trotter and Gleser (1952). A measuring error on two females in their 1952 study led them to publish a correction of some of their regression formulae for Negro females (Trotter and Gleser 1977:355) (Table 8). They state:

The pertinent regression equation (with standard error of estimate), shown in table 9, page 483, was recalculated and found to be:

Stature (cm) = 3.67 Rad + 74.29 ± 4.59.

In table 13, page 495, the estimated mean difference between stature of the living and of the cadaver of 2.5 cm had been subtracted from the constant of each equation. Accordingly the corrected regression equation for estimating living stature in table 13 becomes

Stature (cm) = 3.67 Rad + 71.79 ± 4.59.

A list of corrected lengths of radii from which the statures listed in table 13, appendix 4, page 499, would be estimated are shown in table 1 of this paper (p. 355).

Premortem Stature Measurements

The variation in premortem stature measurements, compared to statural estimates from skeletal remains, has been discussed by Snow and Williams (1971). They find discrepancies resulting from at least four sources: (1) the police may record how tall a person says he/she is; (2) a person may be measured with their shoes on; (3) a person's height may increase one to two inches if they stand fully erect; and (4) a person's stature may be up to one inch shorter in the evening than in the morning.

Himes *et al.* (1977) and Musgrave and Harneja (1978) have reported on stature estimations based on radiographically determined metacarpal lengths. Both studies indicate that the formulae developed compare favorably with other stature-estimation formulae.

A method for assessing maximum long-bone length and living stature from fragmentary long bones is given by Steele and McKern (1969). I have used this method on several occasions and find it difficult to locate the necessary anatomical landmarks on fragmentary bones.

In a landmark study on stature estimation, Genovés (1967) examined the stature of Mesoamericans. His corrected formula for stature calculation is given in Table 9. These formulae produce stature estimates that are significantly different from all other formulae derived by other researchers, though the latter formulae produce similar estimates among themselves. I believe this is due to the fact that Genovés did his study on a very short population. Short pople tend to have different body proportions and would require different regression formulae—thus explaining the difference.

TABLE 8.

Expected Maximum Stature[a] from Maximum Radius Lengths for American Negro Females[b]

Rad.	Stature	Rad.	Stature	Rad.	Stature
186[c]	140	227	155	268	170
189	141	229	156	270	171
191	142	232	157	273	172
194	143	235	158	276	173
197	144	238	159	279	174
199	145	240	160	281	175
202	146	243	161	284	176
205	147	246	162	287	177
208	148	249	163	289	178
210	149	251	164	292	179
213	150	254	165	295	180
216	151	257	166	298	181
218	152	259	167	300	182
221	153	262	168	303	183
224	154	265	169	306	184

[a]The expected maximum stature should be reduced by the amount of .06 (age in years −30) cm to obtain expected stature of individuals over 30 years of age.
[b]From Trotter and Gleser (1977:Table 1).
[c]Measurements given in mm.

TABLE 9.

Calculation of Stature (in cm) from Long-Bones[a] of Mesoamericans[b]

Males:[c]
All bones: Stature = - 2.52 Rad + 0.07 Ulna + 0.44 Hum + 2.98 Fib - 0.49 Tib + 0.68 Fem + 95.113 ± 2.614
Femur: Stature = 2.26 Fem + 66.379 ± 3.417
Tibia: Stature = 1.96 Tib + 93.752 ± 2.815

Females:
All bones: Stature = - 8.66 Rad + 7.37 Ulna + 1.25 Tib + 0.93 Fem + 96.674 ± 2.812
Femur: Stature = 2.59 Fem + 49.742 ± 3.816
Tibia: Stature = 2.72 Tib + 63.781 ± 3.513

[a]Subtract 2.5 cm to obtain the stature while alive.
[b]Working at the level of precision of the Gamma 30 confirmed that, in this case, the humerus contributes practically nothing and therefore was automatically omitted.
[c]An attempt to correct Genovés' formulae was not successful in the second edition. I am indebted to W. H. Birkby (pers. comm.), University of Arizona, for correcting the signs and decimal points for the third edition.

2

THE SKULL OR CRANIUM

The skull is the term used to denote the bony supporting framework of the head. It presents the most complex unit of the skeleton because it functions to protect the brain, one of the most vital parts of the body, as well as the organs of sight, hearing, smell, mastication, and taste. Technically, the cranium is the skull minus the lower jaw, the calvarium is the cranium minus the face, and the calva is the calvarium minus the base.

There are 22 bones in the skull (figures 13–15) (6 unpaired and 8 paired), plus 6 ear bones (3 in each ear), for a total of 28 (Table 10). Although the hyoid often is grouped with the skull, it usually is not considered a part of the skull.

The bones of the skull come together or unite along special serrated and interlocking joints known as sutures. The sutures are irregular linear gaps before the age of 17 but often unite in old age and eventually become obliterated. It should be noted that ossification of the sutures occurs inside the skull (endocranially) first and proceeds toward the outside (ectocranially).

Most sutures take their names from the two bones of the skull that go together to form the suture. However, there are five notable exceptions to this rule:

Suture name	**Location**
Coronal	between frontal and parietals
Sagittal	between the two parietals
Lambdoidal	between parietals and occipital
Basilar	between occipital and sphenoid
Squamosal	between temporal and parietal

One of the first things a student must learn is how to handle a skull. Taken in general the skull is seen as spheroidal in shape with a smooth top, somewhat compressed from side to side, and having an uneven base. To some it resembles a bowling ball, and there is a compulsion to insert one's fingers into the eye orbits or sockets. *This never should be done*. The bones of the medial wall of the eye orbit are paper thin and are broken easily given the slightest pressure.

Always keep in mind the following points when working with a skull:

1. Hold the skull with both hands and make sure you have a firm grip on it at all times.

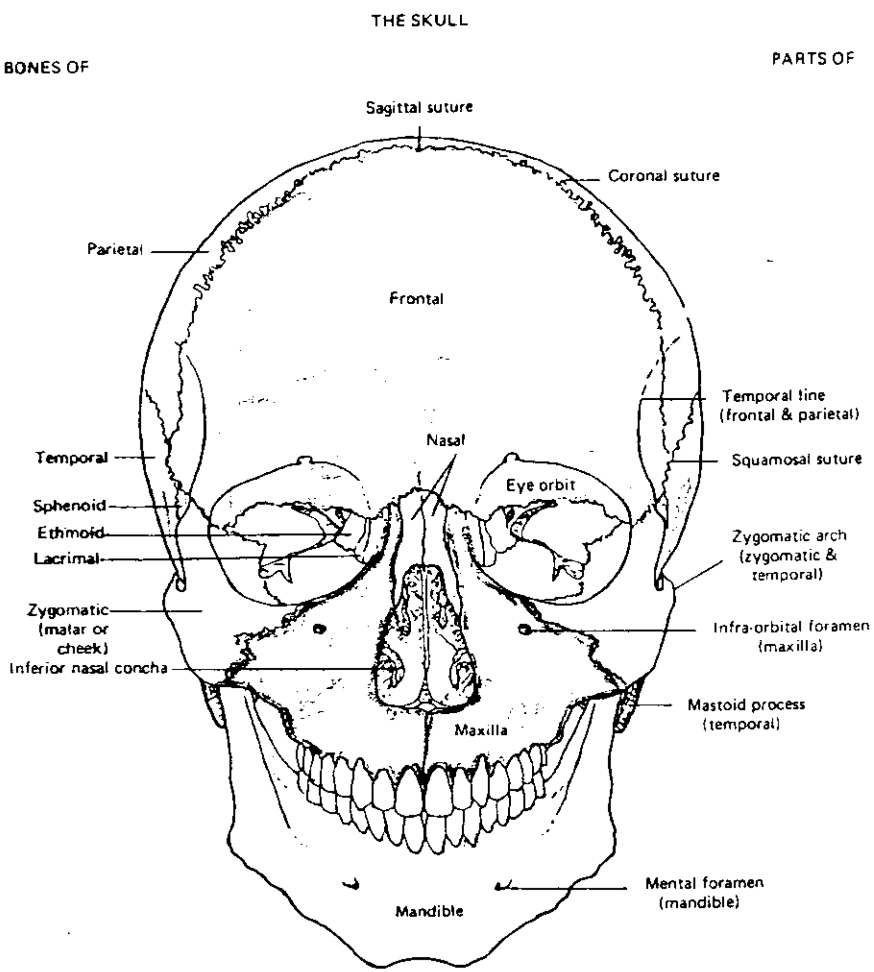


Figure 13. Cranial elements and features, frontal (anterior) view.

2. Care should be taken against breaking teeth when putting jaws together.
3. Never insert the fingers into the eye orbits.
4. Never hold a skull by the zygomatic arch. Often in archaeological specimens this area is fragile or cracked and will break easily.
5. One should not try to hold the skull by inserting the fingers into the foramen magnum, the large hole in the base of the skull through which the spinal column passes.

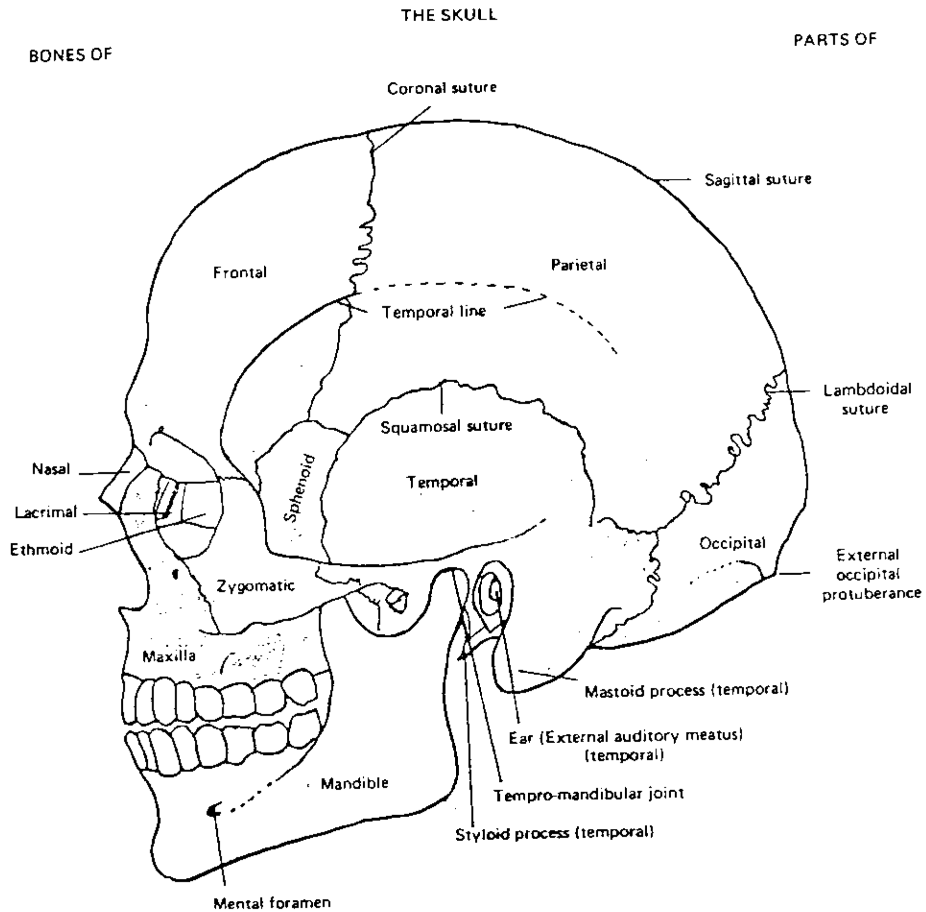


Figure 14. Cranial elements and features, lateral view.

6. Never place the skull on a flat surface (e.g., table) unless it is resting on a bean bag, donut ring, sand box, or some other secure foundation.

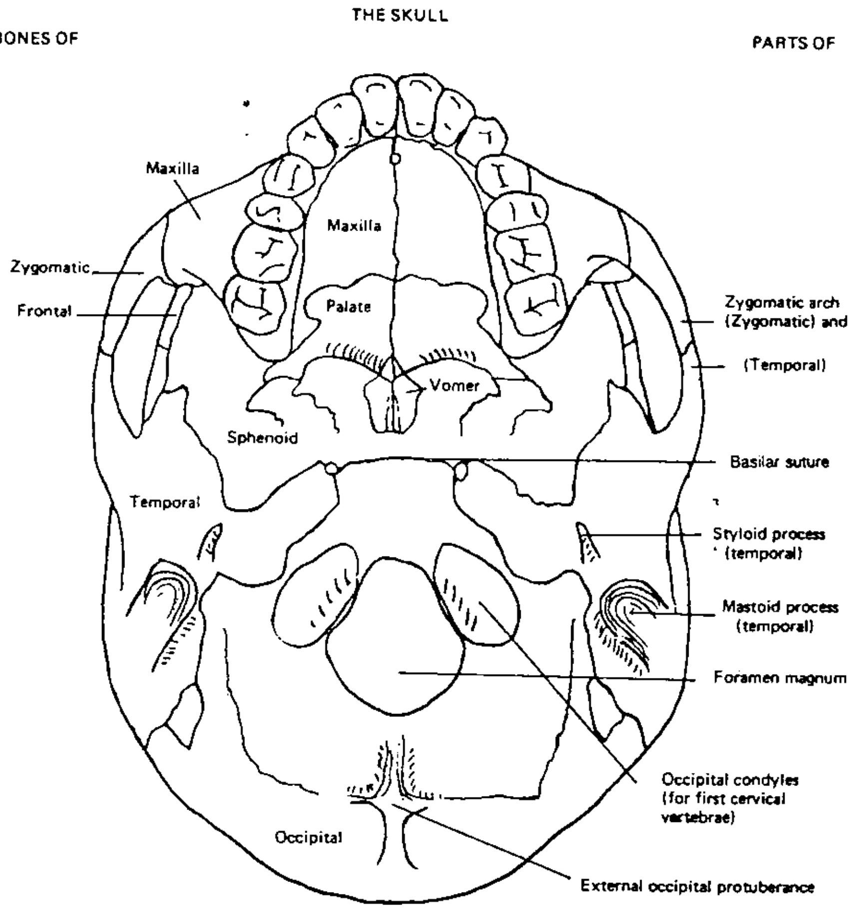


Figure 15. Cranial elements and features, base view.

TABLE 10.
Bones of the Skull

Bone	Number	
	Unpaired	Paired
Cranium		
Frontal	1	
Parietal		2
Occipital	1	
Temporal		2
Sphenoid	1	
Maxilla		2
Nasal		2
Zygomatic (malar or cheek)		2
Mandible	1	
Ethmoid	1	
Lacrimal		2
Palate		2
Vomer	1	
Inferior nasal concha		2
Ear		
Malleus		2
Incus		2
Stapes		2
Associated		
Hyoid	1	

BONES OF THE CRANIAL VAULT

Frontal Bone: Unpaired (Figure 16) (May be divided on midline by Metopic suture)

Lying under the forehead and forming the upper edges of the orbits, or eye sockets, the frontal bone articulates with the parietals, sphenoid, ethmoid, lacrimal, zygomatic, maxilla, and nasal bones.

Anatomical Characteristics of Importance in Identification

Exterior surface

Superciliary arches (brow ridges)—curved projections above orbits.

Supraorbital notch or foramen—a hole or notch, or both, in the supraorbital border for the passage of the supraorbital nerve and artery.

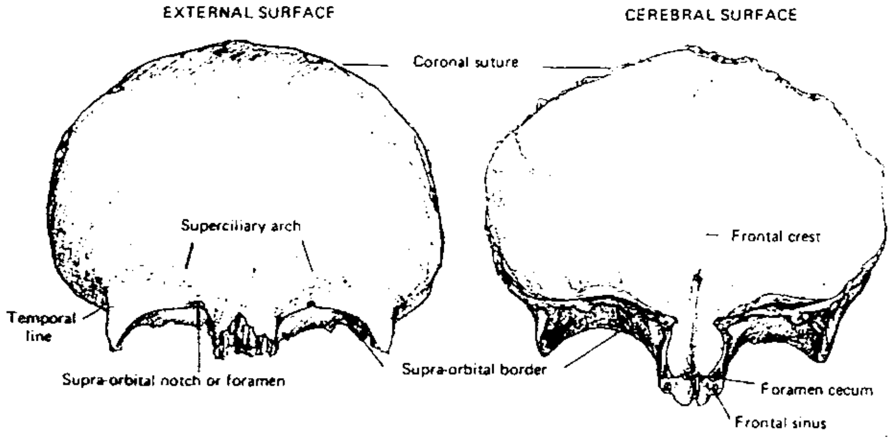


Figure 16. Characteristic features of the frontal bone.

Supraorbital border—upper edge of the eye orbit; often used in sex estimation.

Temporal line—edge of attachment of the temporal fascia and the lower end of the temporal muscle.

Cerebral surface

Frontal crest—a crest on anterior part of the bone that terminates in the foramen cecum.

Foramen cecum—between frontal crest and crista galli of the ethmoid (sometimes transmits a vein from nasal cavity to superior sagittal sinus).

Bones of Similar Shape where Confusion May Arise

The following cranial bones are all flat: parietals, occipital, and temporals. In the postcranial skeleton, the scapula and innominates also have a broad, flat surface.

Information of Importance in Identification

Only the frontal bone forms the upper edge of the orbits.

Smooth areas of the frontal sinuses are located on the cerebral surface between the orbits.

If you find a sinus area on a bone, remember that large sinuses occur on only the frontal, maxilla, and sphenoid.

The cerebral surface of the roof of the orbits has a very characteristic rough surface with furrows and ridges corresponding to the convolutions of the brain. This combination of furrows and ridges is found only on the

The temporal lines are well marked on the external surface of the frontal.

The frontal crest terminates in the foramen cecum located on the anterior border of the frontal bone between the orbits.

The posterior border of the frontal bone is the coronal suture.

Parietal Bone: Paired (Figure 17)

Forming a large part of the roof and sides of the cranium, the parietal bone is interposed between the frontal and occipital bones. It articulates with the occipital, frontal, sphenoid, temporal, and the other parietal.

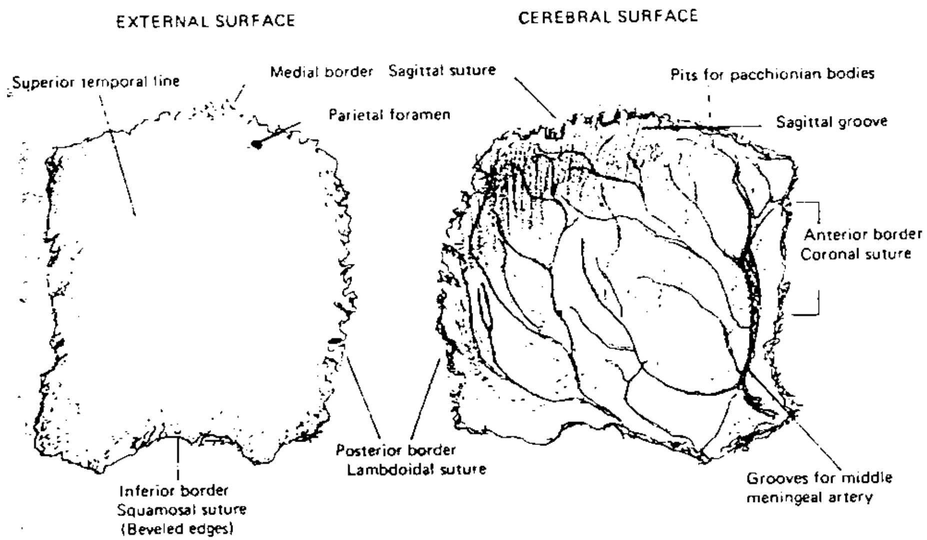


Figure 17. Characteristic features of the parietal (left bone depicted).

Anatomical Characteristics of Importance in Identification

Exterior Surface

Superior temporal line.

Parietal foramen—found in the posterior one-third near the sagittal suture. They usually occur in pairs but may not be present and are seldom multiple.

Frontal (anterior) border—the border along the coronal suture that is slightly concave and is less serrated than either the sagittal or lambdoidal sutures.

Medial border—identified by the sagittal suture, which is more serrated than the coronal suture and is relatively straight.

Posterior border—the lambdoidal suture is convex and deeply serrated.

Inferior border or squamosal border—is one of the few with a beveled edge (Figure 18). The border exhibits a series of different patterns and in general is concave to fit the convex temporal bone. Divisions of the squamosal border are:

Area	Pattern	Articulates with
Anterior	thin and beveled	sphenoid
Medial	thin and beveled	temporal
Posterior	thick and serrated	mastoid portion of temporal

Figure 18. Beveled edge of the inferior/squamosal suture of the parietal.

Cerebral Surface

Grooves for the middle meningeal vessels always run up and back from the sphenoid angle. Note that there is a heavy groove just posterior to the coronal (anterior) border.

The sagittal groove (for the superior sagittal sinus) runs along the inside of the sagittal suture.

Pits for the pacchionian bodies sometimes are seen along the sides of the sagittal groove, especially in its anterior one-half.

Bones of Similar Shape where Confusion May Arise

The following cranial bones are all flat: frontal, occipital, and temporal. In the postcranial skeleton, the scapula and innominate also have a broad flat surface.

Information of Importance in Identification

Always check the edges of the bone carefully. If the edges are serrated it will be a cranial bone.

The parietals are shallow, bowl-shaped bones with sutures on all four edges.

Check for the lines of the middle meningeal vessels (cerebral surface). These generally are found on the parietals and temporals, though they occasionally occur on the posterior edge of the frontal.

Side Identification

Always try to place any bone as it is in your body. This will help in orienting the bone.

The concave, beveled suture always is down or away from the midline.

When the parietal foramina are present, they always occur in the posterior third of the sagittal suture near the midline.

The most deeply serrated suture is the lambdoidal, which always is posterior.

The grooves for the middle meningeal vessels always run up and back. If you are holding the parietal in a position so that it is in close relationship to your own parietal, and the grooves for the middle meningeal vessels are running up and forward, you must change the bone to the opposite side of the body to have it oriented properly.

Occipital Bone: Unpaired (Figure 19)

Situated in the posterior and inferior part of the cranium, the occipital bone is connected by sutures with the two parietals (lambdoidal suture), the two temporals (along the mastoid margin), and the sphenoid (basilar "suture") (Figure 19). This is the only bone of the skull that articulates with the postcranial skeleton. The articulation is through the occipital condyles with the first cervical vertebra (atlas). In a few individuals the occipital may articulate with the dens of the epistropheus (axis). The largest hole of the skull, the foramen magnum, through which the spinal cord enters the skull, is located on the inferior surface between the occipital condyles.

The occipital develops in four parts (Figure 20):

Basilar—anterior to foramen magnum; articulates at the basilar suture with the sphenoid and is the smallest of the four parts.

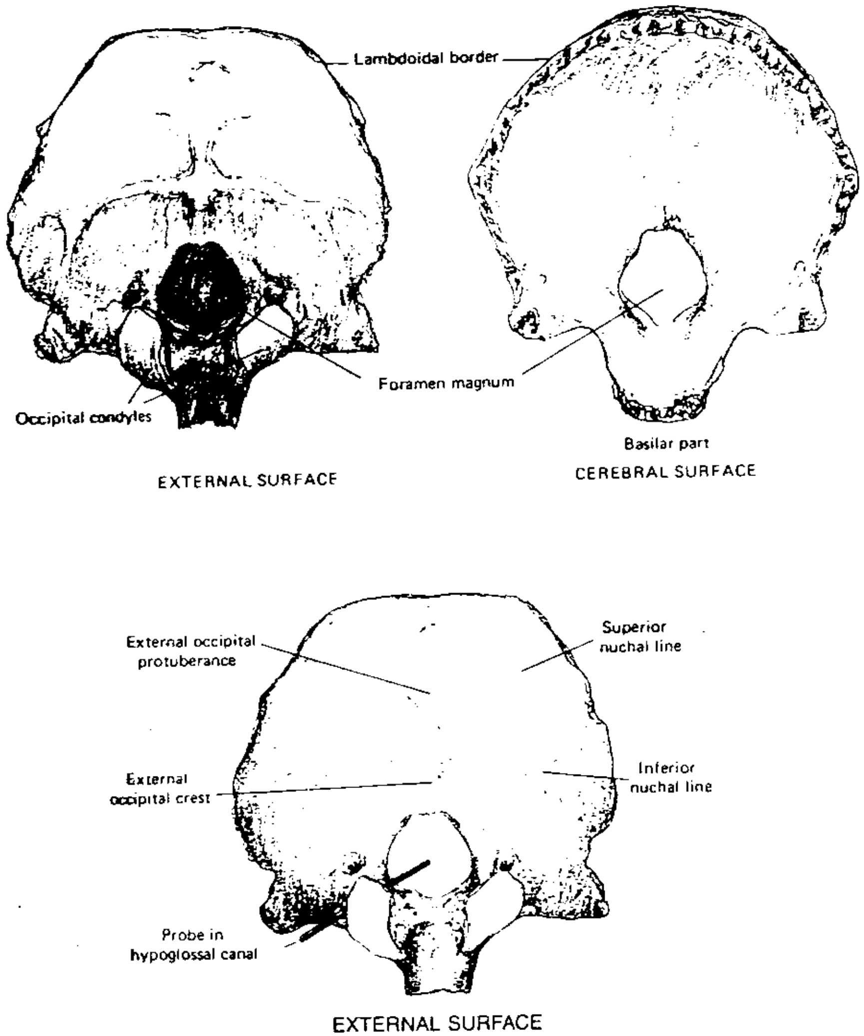


Figure 19. Characteristic features of the occipital.

Two laterals—form the sides of the foramen magnum; they articulate with the temporal bones. The major part of the occipital condyles is located on the lateral portions.

Squamous—posterior to the foramen magnum; the largest of the four parts, composed of the interparietal and supraoccipital portions.

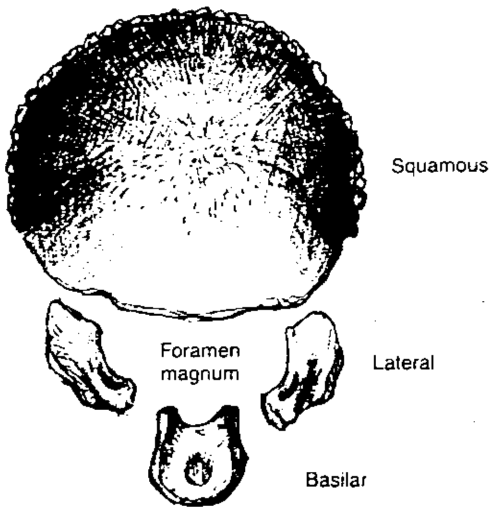


Figure 20. Occipital at birth.

Anatomical Characteristics of Importance in Identification

Exterior Surface

External occipital protuberance—midway between the superior border (lambdoidal suture) and the posterior margin of the foramen magnum.

Superior nuchal line—arching laterally on each side from the external occipital protuberance toward the lateral angles of the bone.

Inferior nuchal line—runs laterally from the middle of the external occipital crest to the jugular process.

External occipital crest—medium ridge running from external occipital protuberance to foramen magnum.

Occipital condyles—articular surfaces for the first cervical vertebra.

Cerebral Surface

Internal occipital crest—note that the internal surface is concave and marked by two grooved ridges that cross each other at the internal occipital protuberance and divide the surface into four parts. The internal occipital crest is a median ridge that divides as it approaches the foramen magnum and becomes less defined.

Bones of Similar Shape where Confusion May Arise

The following cranial bones are all flat: frontal, parietals, and temporals. In the postcranial skeleton the scapula and innominates also have a broad flat surface.

Information of Importance in Identification

If you have a flat cranial bone, look first for the the foramen magnum.

Articular surfaces occur on only three cranial bones: (1) occipital with the occipital condyles, (2) temporal with the temporomandibular joint, and (3) the condyles of the mandible.

The occipital condyles are convex, the temporomandibular articular surfaces are concave.

The lambdoidal suture is deeply serrated.

The internal configuration exhibits two crests that divide the surface into four parts, which is a feature distinguishing it from the frontal bone.

Temporal Bone: Paired (Figure 21)

Located at the side and base of the cranium, the temporal bone is below the parietal, posterior to the sphenoid, and anterior to the occipital. The organs of hearing and the articulation for the mandible are contained in this bone. Each one also articulates with a zygomatic (malar, or cheek) bone through the zygomatic arch.

The temporal bone has three parts:

Squamous—flat anterior and superior part that articulates with the sphenoid and through a beveled suture with the parietal bones; includes the zygomatic process.

Mastoid—that area behind the ear opening (external auditory meatus) that is thick and conical and projects downward.

Petrous—medial to the last two, lies in the base of the skull and contains the inner ear.

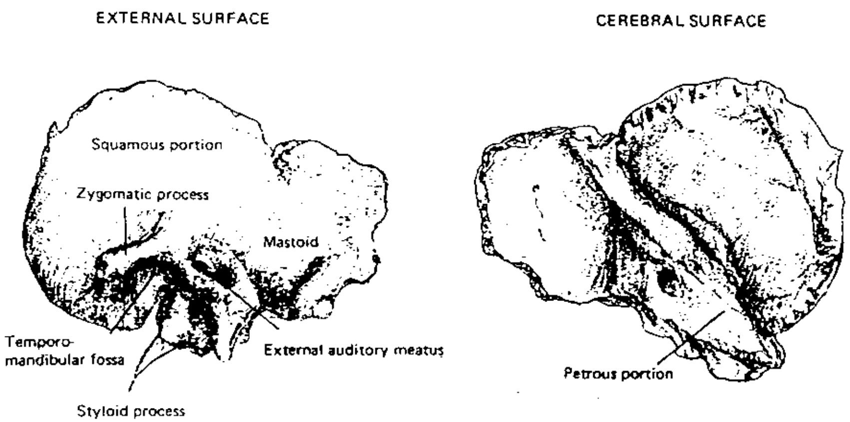


Figure 21. Characteristic features of the temporal (left bone depicted).

Anatomical Characteristics of Importance in Identification

Exterior Surface

Zygomatic process—that portion of the bone extending forward and articulating with the malar bone to form the zygomatic arch.

Mandibular fossa (temporomandibular joint)—the articular surface for the condyle of the mandible. It is immediately anterior to the ear hole (external auditory meatus) and just below the posterior end of the zygomatic arch.

External auditory meatus—the ear opening. When the bone is in proper anatomical position it is posterior to the zygomatic process but anterior to the mastoid process.

Mastoid process—a cone-shaped projection pointing downward behind the external auditory meatus. It is the bony structure that can be felt back of the ear.

Styloid process—on the base of the skull and medial to the mandibular fossa, external auditory meatus, and mastoid process. It is a slender, cylindrical spur that projects down and forward and gives attachments to muscles, especially those involved in speech.

Cerebral Surface

Petrous portion—projects almost at a right angle from the squamous and mastoid portions; situated to the medial side of these parts and participates in the formation of the base of the skull. The petrous portion fills the area in the base of the skull between the basilar and lateral portions of the occipital bone and the greater wings of the sphenoid. It functionally is the most important part of the temporal bone, for it surrounds the essential part of the organs of hearing.

Grooves for the middle meningeal vessels—often can be seen along the anterior and superior borders.

Bones of Similar Shape where Confusion May Arise

This is a complicated bone and when fragmentary can resemble almost any bone to the unexperienced. Bones often confused with the temporal are the parietal (because of the beveled suture), the occipital and the frontal. Postcranial bones having flat surfaces are the scapula and innominate.

Side Identification

When held in anatomical order the zygomatic process always points forward and the mastoid process downward.

The mandibular fossa always is in front of the ear opening (external auditory meatus).

The squamosal border is beveled with a sharp edge and always is superior.

The styloid process always points downward.

The mastoid process always is posterior to the ear opening (external auditory meatus).

Sphenoid Bone: Unpaired (Figure 22)

The sphenoid is a very irregular bone that helps form the floor and sides of the cranial vault. Composed of a body, two pairs of lateral expansions called greater and lesser wings, and a pair of processes that project downward (the pterygoid processes), it is in general a U-shaped bone. It articulates with the occipital, parietals, frontal, ethmoid, temporals, palatine, vomer, zygomatics, and sometimes with the maxillae.

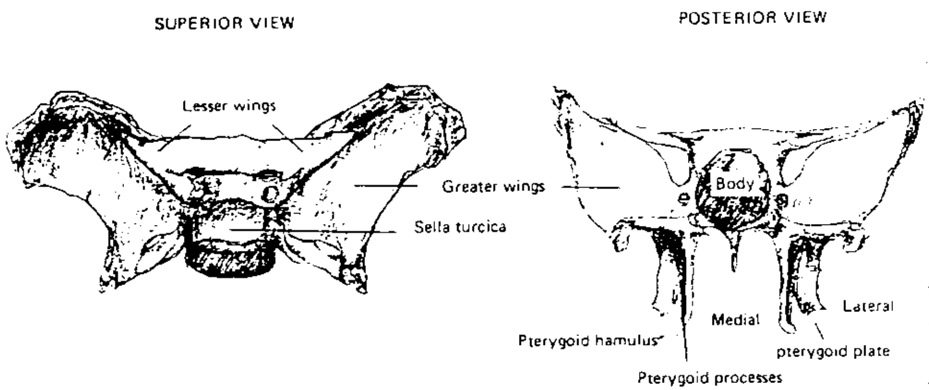


Figure 22. Characteristic features of the sphenoid.

Anatomical Characteristics of Importance in Identification

Exterior Surface

Greater wings—plates of bone that extend laterally from the body and bend superiorly near their tips. They form the portion of the skull between the temporals and frontal.

Pterygoid processes—project downward from the junction of the body and greater wings. These are best seen as the structures at the posterior end of the tooth row. Each projection consists of two plates (the pterygoid plates). The lateral one is shorter and broader and the medial is longer and narrower. They unite in front but diverge behind.

Cerebral Surface

Lesser wings—two thin, triangular plates of bone extending laterally and almost horizontally from the anterior portion of the body. They are on the cerebral surface immediately anterior to the greater wings.

Sella turcica—a depression on the superior surface of the body. The pituitary gland is housed in this depression posterior to the lesser wings.

Bones of Similar Shape where Confusion May Arise

Because of its complicated structure, it is possible to confuse this bone with most of the cranial bones. Those most frequently confused are the temporal, parietal, occipital, and frontal.

Information of Importance in Identification

This bone has a number of sharp projections.

It has many foramina.

Most of the bone is fragile.

The body contains the sphenoidal sinus.

Remember that sinuses only occur in the frontal, maxilla, zygomatic, and sphenoid.

BONES OF THE FACE

Maxilla (Upper Jaw): Paired (Figure 23)

One of the largest bones of the face, it supports the upper teeth and helps to form the orbits, the hard palate, and the nasal fossa. It is divided into a body and four processes that are listed below. The two maxillae articulate with each other and with the frontal, nasals, lacrimals, ethmoid, palate bones, vomer, zygomatics, and interior nasal conchae. In some cases the maxillae may articulate with the sphenoid.

Anatomical Characteristics of Importance in Identification

Body—this is the main portion of the bone. It is hollow because of the maxillary sinus.

Infraorbital foramen—located just below the inferior margin of the eye orbits. Terminal branches of the infraorbital nerves and blood vessels emerge here.

Anterior nasal spine—this is a sharp anterior projection along the midline at the base of the nose.

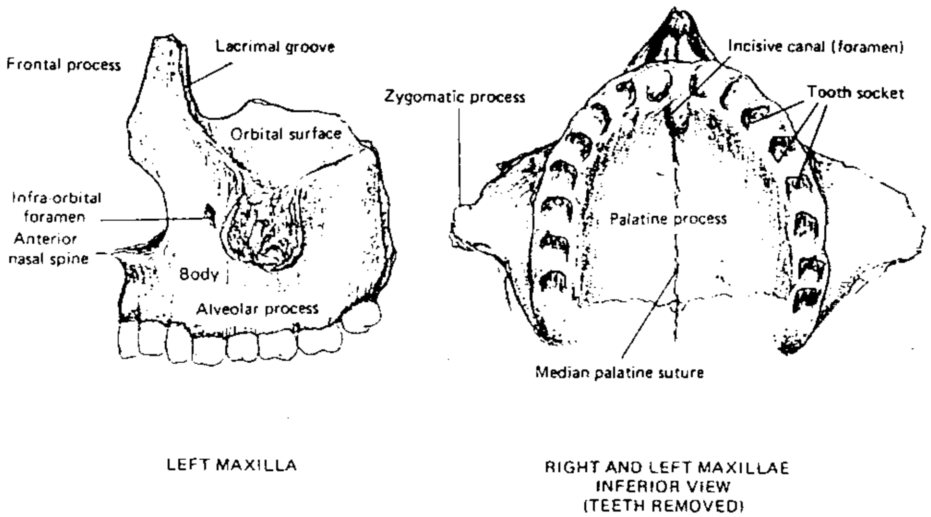


Figure 23. Characteristic features of the maxilla.

Frontal process—a slender portion of the bone that rises from the body and helps to form the lateral wall of the nasal fossa. It articulates with the frontal bone and with the lacrimal bone forms the lacrimal groove on the anterior medial surface of the eye socket.

Zygomatic process—below the eye socket; it is a lateral projection from the body that articulates along a diagonal suture with the malar, or zygomatic, bone.

Palatine process—forms the roof of the mouth. It projects medially from the body and joins the process from the opposite side at the midline. This process forms three-fourths of the hard palate.

Incisive foramen—in the midline behind the central incisors is a large foramen or canal formed by the right and left maxillae.

Alveolar process—that portion of the bone that extends inferiorly from the body and holds the upper teeth. There usually are eight tooth sockets in each maxillae arranged in a U-shaped arch.

Bones of Similar Shape where Confusion May Arise

The mandible because of the teeth and/or tooth sockets.

Side Identification

This is not a difficult bone to side if oriented in anatomical position.

Remember that the major sinuses are found in the maxilla. Other bones with sinuses are the frontal, sphenoid, and zygomatic.

The incisive foramen is along the midline.
The zygomatic process extends away from the midline.

Age Estimation

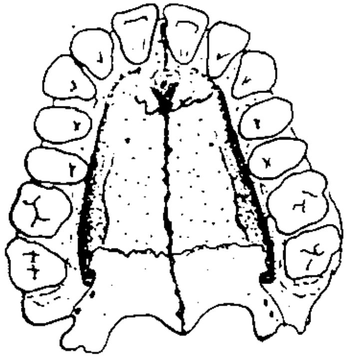
Research by Mann *et al.* (1987) suggests that the four maxillary sutures are general age indicators (incisive, interpalatine, intermaxillary, and palatomaxillary). At birth the maxillary sutures are well defined with gaps existing along their margins. The surface of the maxilla in young individuals exhibits a rough, bumpy appearance (Figure 24a). Increasing age results in a progressively smoother surface as the bumps and sutures slowly disappear (Figure 24b, c). The sutures of importance in estimating age are the incisive and interpalatine (Figure 24b).

The incisive suture extends from between the lateral incisors and canines and terminates at the posterior portion of the incisive fossa. Obliteration commences between the incisors and canines (usually symmetrically) and progresses toward the incisive fossa (Figure 24b). The interpalatine suture is identified as the continuation of the intermaxillary suture and is measured (for percentage purposes) from the most posterior junction of the intermaxillary and palatomaxillary sutures and extends to the posterior point of the posterior nasal spine (Figure 24b). Current research soon may permit the estimation of age based on the amount of interpalatine obliteration (percentage). By visually determining the amount of sutural obliteration of the four maxillary sutures, an approximate age range may be calculated. Preliminary studies conclude that the following general age categories can be suggested based on the amount of incisive and interpalatine sutures obliterated:

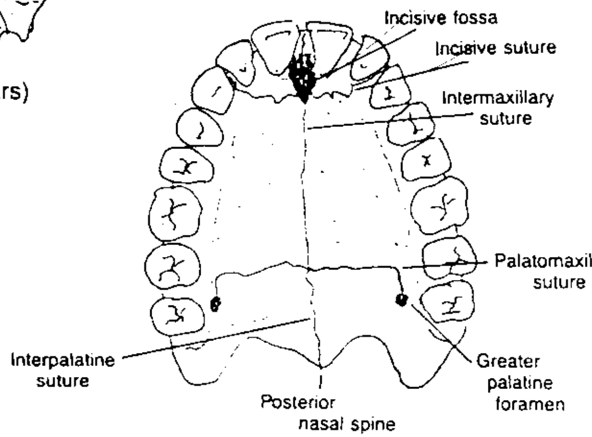
Subadult—Little (possibly less than one-half) or no obliteration of the incisive suture; no obliteration of other maxillary sutures; gaps may be present between one or all sutures; sutures rough.

Adult (18 +)—Some obliteration of the interpalatine suture and/or more than one-half of the incisive suture; surface texture may appear somewhat smoother than subadult.

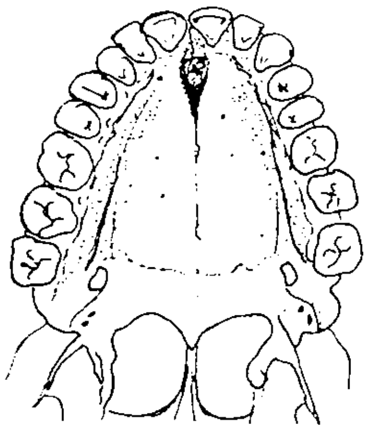
Older adult (50 +)—Obliteration of portions of 3 or more sutures; surface of the maxilla smooth, possibly pitted along faded suture lines. If all sutures are obliterated the individual probably is at least 50 years of age. It must be noted, however, that some individuals may be more than 50 years of age and not exhibit complete obliteration of even the interpalatine suture. Adults may retain a visible remnant of the incisive suture at any age.



a Subadult (14 years)



b Maxilla (sutures identified)



c Older adult (64 years)

Figure 24. General age indication based on the maxillary sutures: a, subadult (14 years); b, maxilla (sutures identified); c, older adult (64 years).

Nasal Bone: Paired (Figure 25)

This is a small bone that forms the bridge of the nose. Each bone is thicker and narrower superiorly, thinner and wider inferiorly, and presents two surfaces and four borders. The nasal bones articulate with each other and with the frontal, the two maxillae, and the ethmoid.

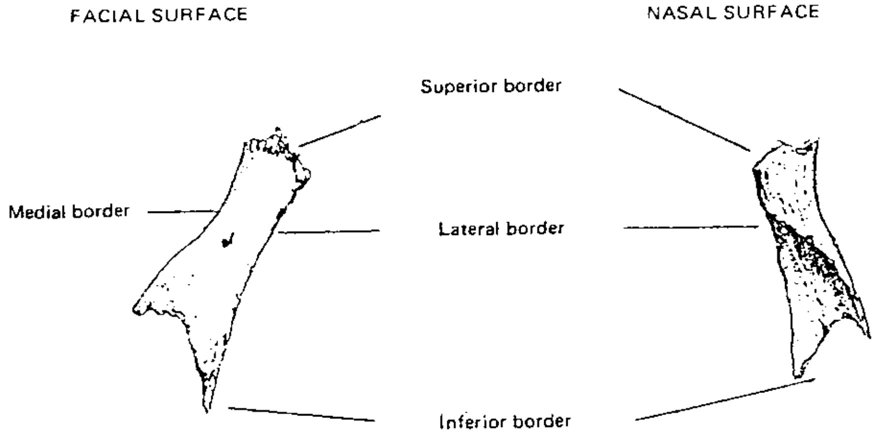


Figure 25. Characteristic features of the nasal bone (left bone depicted).

Anatomical Characteristics of Importance in Identification

Medial border—a finely serrated articular border where the two nasal bones come together forming the internasal suture. Of the three articular edges this is intermediate in length.

Lateral border—the longest of the three articular edges and is the border that joins the maxilla. It is more deeply serrated than the medial border but not as serrated as the superior. Forms the nasomaxillary suture.

Superior border—the shortest and most deeply serrated of the three articular borders. Forms the nasofrontal suture.

Inferior border—presents the only nonarticular border. The bone is thin here and presents a sharp edge.

Bones of Similar Shape where Confusion May Arise

Possibly the vomer.

Side Identification

Remember that there are three articular borders and one nonarticular border.

The longest articular border is the lateral edge (nasomaxillary suture).

When held in approximate anatomical position with the nonarticular surface down or away from you, the nasomaxillary suture will be on the same side the bones come from.

The finely serrated articular border is the medial border.

Zygomatic (Malar, or Cheek) Bone: Paired (Figure 26)

This bone forms the prominence of the cheek and can be felt under the skin just below and lateral to the eye socket (Figure 26). It articulates with the zygomatic portion of the temporal bone to form the zygomatic arch. It also articulates with the maxilla, frontal, and sphenoid. The zygomatic bone can be called by either of two other terms—malar or cheek bone—but the term zygomatic should be learned, as it is the most frequently used term and will aid the student in remembering the zygomatic arch.

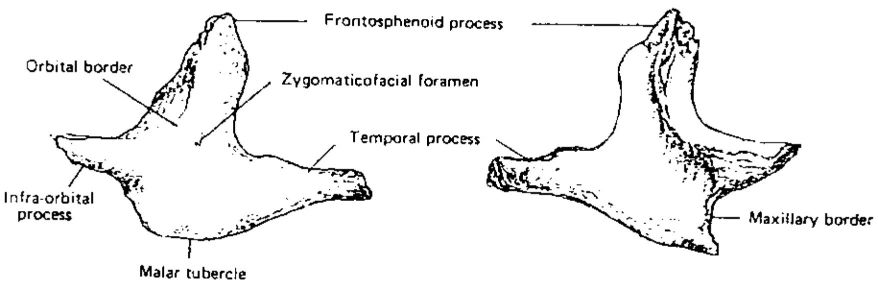


Figure 26. Characteristic features of the zygomatic (malar, cheek) bone (left bone depicted).

Anatomical Characteristics of Importance in Identification

Infraorbital process—the anterior portion just below the eye socket that articulates with the maxilla.

Frontosphenoid process—the superior projection of the bone that forms the lateral edge of the eye socket. On the surface of the bone just below this process, the zygomaticofacial foramen sometimes is found.

Zygomaticofacial foramen—the name applied to one and sometimes two or more small holes on the anterior surface of the bone. They transmit the zygomaticofacial nerves and vessels.

Temporal process—the posterior projection that articulates with the temporal bone to form the zygomatic arch.

Malar tubercle—the blunt, rounded, inferior angle of the bone.

Bones of Similar Shape where Confusion May Arise

The frontal and maxillae because of the edges of the eye orbits. In the postcranial skeleton some students confuse the edges of the scapulae with the zygomatic.

Side Identification

The infraorbital process ends in a sharp point and always is below the eye orbit and points toward the nose.

The maxillary border is deeply serrated and angles from the edge of the eye orbit (infraorbital process) laterally.

This bone is thin and has an anterior and a temporal surface.

Mandible: Unpaired (Figure 27)

The mandible or lower jaw is the largest and strongest bone of the face. It is the most movable bone of the skull, articulating through the condyles with the temporal bones at the temporomandibular joints (Figure 27). The bone supports the lower teeth, which meet those of the maxilla at the occlusal plane.

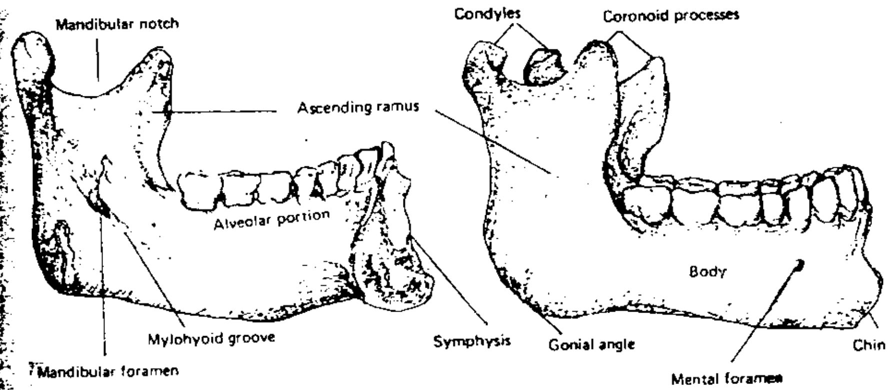


Figure 27. Characteristic features of the mandible.

Anatomical Characteristics of Importance in Identification

Body—the anterior and horizontal portion of the bone that is shaped like a horseshoe. It sometimes is known as the horizontal ramus.

Ascending ramus—consisting of a right and a left, these are the broad, vertical projections that terminate posteriorly with the condyles for articulation with the temporal bones and anteriorly with the nonarticular coronoid processes.

Condyle—oval in form and joins the temporal bone through the articular surface (the head). It is the posterior projection of the ascending ramus.

Coronoid process—the anterior superior projection of the ascending ramus. A flattened and triangular portion of the bone gives attachments to the temporal and masseter muscles. This projection is separated from the condyle by the mandibular notch.

Mandibular notch—a deep notch between each anterior coronoid process and the posterior condyles (condyloid process).

Symphysis—on the midline of the body may be seen a faint line where the two original separate halves of the bone united. The two halves usually unite just prior to birth.

Mental foramen—on the external surface of the body and just below the premolar teeth. It is located approximately midway between the upper and lower border and transmits the mental nerve and vessels.

Mandibular foramen—two large holes on the medial surface and approximately in the middle of the ascending ramus. The mandibular nerve enters the bone here to innervate the teeth in the lower jaw.

Mylohyoid groove—runs obliquely downward and forward from the mandibular foramen and holds the mylohyoid nerve and artery. Sometimes this groove is bridged over with bone to form a mylohyoid bridge.

Gonial angle—the angle formed by the meeting of the thick posterior border of the horizontal ramus and the inferior border of the ascending ramus. It usually is everted but can occur as a straight or inverted angle.

Chin—a structure found only in man; the anterior projection of the inferior border of the body of the mandible. (Of the fossil men only *Homo sapiens* possessed a chin, beginning ca. 35,000–40,0000 B.P. with the appearance of Cro-Magnon man.)

Alveolar process—the superior border of the body of the mandible that is hollowed out into sockets for the teeth. In old age there may be resorption when the teeth are lost.

Bones of Similar Shape where Confusion May Arise

The maxilla because of the teeth. Remember that there are no sinuses at the base of the mandibular teeth as there are in the maxilla. The base of the alveolar portion is expanded in the maxilla while it is narrow, dense bone in the mandible.

Side Identification

Although this is an unpaired bone, it frequently is broken and the side must be identified.

The teeth always are superior and the ascending ramus posterior.

The mental foramen is on the external surface, and the mandibular foramen is on the medial surface.

The mylohyoid groove extends downward and forward from the mandibular foramen.

BONES OF THE EYE ORBIT, PALATE, AND NOSE

Ethmoid Bone: Unpaired (Figure 28)

A bone of delicate texture, the ethmoid helps to form the floor of the anterior cranial fossa and enters into the formation of the walls of the orbital and nasal fossa (Figure 28). It is shaped much like a fallen capital letter "E," with an extended middle portion. It articulates with the frontal, sphenoid, two nasals, vomer, two lacrimals, two maxillae, two inferior nasal conchae, and the two palatine bones.

Anatomical Characteristics of Importance in Identification

Cribriform plate—resembling a piece of screen wire, it is a horizontal plate containing many foramina for passage of the olfactory nerves. The crista galli is located in the center of the anterior portion.

Crista galli—a thick, triangular plate of bone extending above the cribriform plate. The highest point is in front, and its short anterior border joins the frontal bone to form the foramen cecum.

Perpendicular plate—extending below the crista galli and at right angles to the cribriform plate, it forms the upper and posterior one-third of the nasal septum.

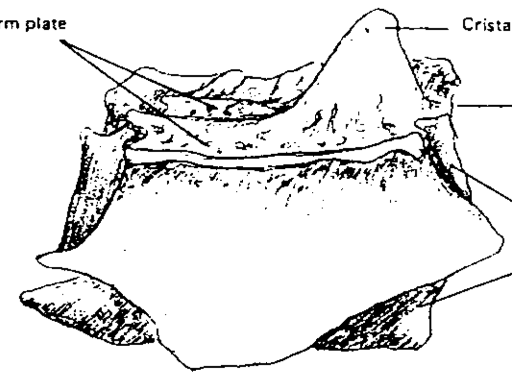
Bones of Similar Shape where Confusion May Arise

None.

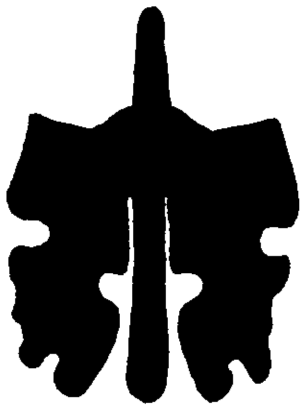
Information of Importance in Identification

The cribriform plate and crista galli are very diagnostic.

LATERAL VIEW



a



b

Figure 28. Characteristic features and cross section of the ethmoid: a, lateral view; b, cross section.

Lacrimal Bone: Paired (Figure 29)

The lacrimal is a very thin, delicate bone situated in the anterior part of the medial wall of the eye socket (Figure 29). Immediately posterior to the frontal portion of the maxilla, it articulates with the ethmoid, maxilla, frontal, and inferior nasal concha.

LATERAL VIEW

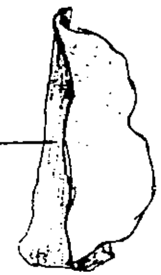


Figure 29. Characteristic features of the lacrimal (left bone depicted).

Anatomical Characteristics of Importance in Identification

Lacrimal groove—in the anterior portion of the bone is a deep depression. With the maxilla this forms the lacrimal groove that holds the lacrimal sac and duct.

Bones of Similar Shape where Confusion May Arise

None.

Side Identification

Because of the extremely delicate nature of the lacrimal, one rarely has the opportunity to side this bone. However, the lacrimal groove always is anterior and is defined more clearly on the inferior than on the superior part of the bone.

Palate Bone: Paired (Figure 30)

The two palate bones form the posterior part of the hard palate and part of the lateral wall of the nasal fossa (Figure 30). They are delicate, L-shaped bones. The palatine bones articulate with both maxillae, the sphenoid, the vomer, both interior nasal conchae, the ethmoid, and its counterpart on the opposite side.

Anatomical Characteristics of Importance in Identification

Horizontal portion—forms the posterior part of the bony portion of the roof of the mouth. It articulates anteriorly with the palatine process of the

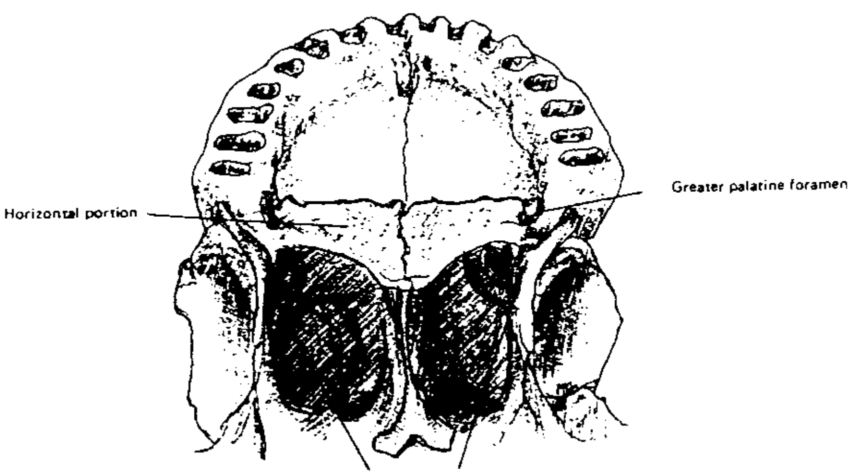


Figure 30. Characteristic features of the palate bones.

maxilla. The greater palatine foramen is located laterally at its junction with the perpendicular portion.

Perpendicular portion—thinner than the horizontal portion, this portion forms the posterior lateral walls of the nasal fossa.

Greater palatine foramen—a large foramen at the edge of the hard palate and above the second and/or third molars.

Bones of Similar Shape where Confusion May Arise

Sphenoid, because of its fragile structure and L-shape. Maxilla, because of the surface of the roof of the mouth.

Side Identification

The horizontal portion is the least fragile and most easily recognized.
Remember that the posterior border is a nonarticular edge.
The greater palatine foramen always is lateral.

Vomer: Unpaired (Figure 31)

Sometimes called the ploughshare bone, the vomer is a thin, flat bone that lies in the median plane and forms part of the lower and posterior

portions of the nasal septum (Figure 31). It articulates with the ethmoid, sphenoid, two palate bones and the two maxillae.

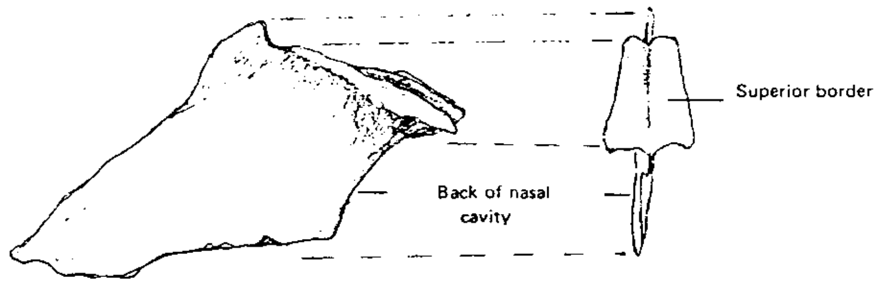


Figure 31. Characteristic features of the vomer.

Anatomical Characteristics of Importance in Identification

Superior border—the thickest part of the bone; articulates with the sphenoid and is expanded laterally into two small wings.

Bones of Similar Shape where Confusion May Arise

Especially the greater and lesser wings of a fragmentary sphenoid, and possibly the nasal.

Information of Importance in Identification

The expanded superior border is characteristic and offers the best area of identification.

Inferior Nasal Concha: Paired (Figure 32)

Also known as the turbinate bone, the inferior nasal concha is a slender, very fragile, scroll-like bone attached by its upper margin to the lateral wall of the nasal fossa (Figure 32). The inferior border is free. The superior and middle nasal conchae are parts of the ethmoid bone. The inferior nasal concha articulates with the two maxillae, two lacrimals, two palate bones, and the ethmoid.

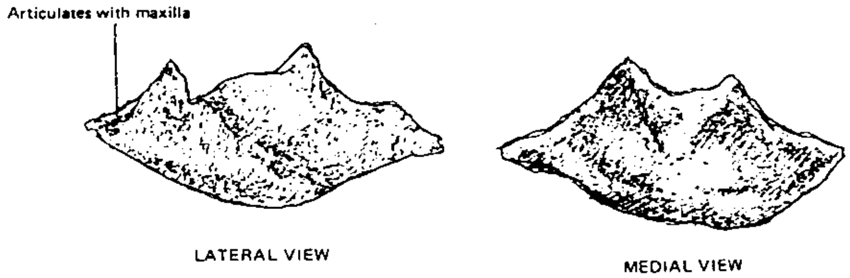


Figure 32. Characteristic features of the inferior nasal concha.

Anatomical Characteristics of Importance in Identification

Note the rough and uneven texture of the surface. When air is drawn in through the nose this uneven texture causes turbulence and aids in smell.

Bones of Similar Shape where Confusion May Arise

The cerebral surface of the frontal bone above the eye orbits has a rough texture and when fragmentary may cause confusion.

BONES OF THE EAR

Auditory Ossicle: Paired (Figure 33)

The auditory ossicles consist of three bones in each ear: the malleus, incus, and stapes (Figure 33a).

Malleus (Hammer)

This is the largest and most external of the auditory ossicles and is attached to the tympanic membrane (Figure 33b). Its club-shaped head articulates with the incus.

Incus (Anvil)

Situated between the malleus and the stapes, it presents a body and two processes (Figure 33c). It is the middle of the three ossicles of the ear.

Stapes (Stirrup)

This is the innermost of the ossicles of the ear (Figure 33d). Shaped somewhat like a stirrup, it articulates by its head with the incus, and its base is inserted into the fenestra ovalis.

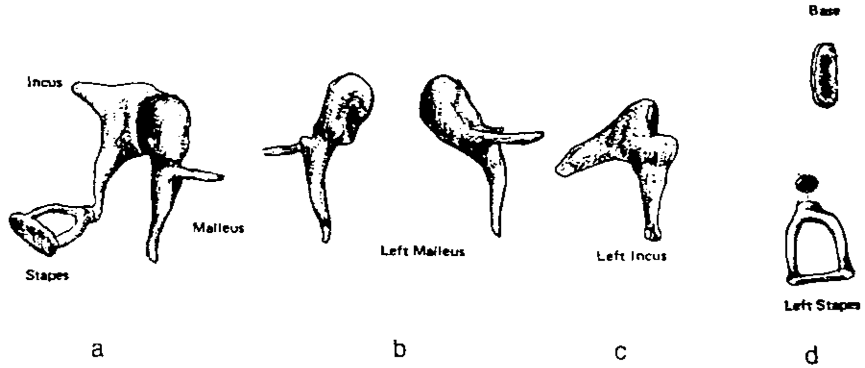


Figure 33. The auditory ossicles: a, malleus, incus, and stapes shown in articulation; b, malleus; c, incus; d, stapes and base.

MISCELLANEOUS

Hyoid Bone: Unpaired (Figure 34)

Situated in the anterior part of the neck, the hyoid does not articulate with any other bone. It supports the tongue and gives attachments to numerous muscles used in speech.

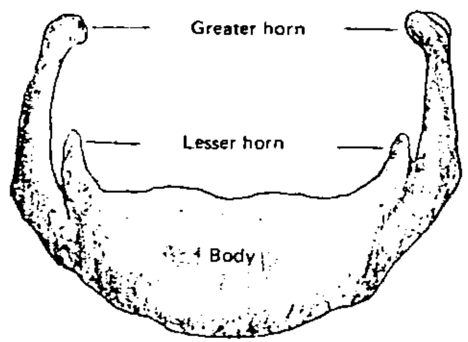


Figure 34. Characteristic features of the hyoid.

Anatomical Characteristics of Importance in Identification

Body—the central portion of the bone that is situated horizontally across the midline of the neck just inferior and posterior to the mandible.

Greater horns—project upward and backward from the sides of the body.

Lesser horns—may be present (and in some individuals are cartilaginous) and are small conical processes that project upward and slightly backward from the anterior surface of the body.

Bones of Similar Shape where Confusion May Arise

The sphenoid because of the greater and lesser wings and the zygomatic and temporals because of the zygomatic arch, which to some resemble the greater horns. In the postcranial skeleton the sphenoid is confused with the vertebrae (i.e., their posterior and lateral projections).

Information of Importance in Identification

A few minutes studying this bone should result in a fairly comprehensive knowledge of it. Both pairs of horns are slender and project backward and upward from the body.

MEASUREMENTS OF THE SKULL

Following the publication of Washburn's (1951) *The New Physical Anthropology*, there has been a tendency to discredit the importance of measurements in physical anthropology. I believe that this was not Washburn's intent; rather he was cautioning against taking long lists of anthropometic measurements just for the sake of taking measurements. The simple measuring of every angle, protuberance, and bone does not aid in a more accurate description of a skeleton or a skeletal population.

The researcher must first know what type of information he is seeking. Anthropometry, then, offers only one means of obtaining the desired data. Howells' (1969) article, "Criteria for selection of osteometric dimensions," is recommended strongly for anyone planning to measure a single skull, bone, or entire population.

Anthropometric measurements are not outdated but rather are techniques for obtaining precise data that then can be evaluated using univariate or multivariate statistical techniques. The use of anthropometric measurements in multivariate analyses can be found in Giles (1964, 1970a, 1970b); Giles and Elliot (1962, 1963); and Howells (1969a, 1969b, 1970a, 1970b).

This manual was written for the purpose of training students and for

use by professional anthropologists who need to use the techniques of physical anthropology to secure data to solve related problems. Information on the following measurements is provided to aid in training the unskilled in the use of instruments and techniques. Measurements taken inaccurately or taken from the wrong anatomical landmarks are not only useless but are a waste of time for the researcher.

Anthropometric measurements are important. So long as researchers wish to compare skeletal populations, some type of measurements must be used. A knowledge of the proper instruments, techniques, and anatomical landmarks will aid the researcher in obtaining accurate raw data for further use. These data may be used in conjunction with other techniques in physical anthropology such as blood typing, dermatoglyphics, and chemical and microscopic analyses to aid us in our understanding of man.

Anthropometry is a technique for measuring men, both living and dead, and can be divided into four branches:

- Somatometry—measurement of the body
- Cephalometry—measurement of the head and face
- Osteometry—measurement of the skeleton and its parts
- Craniometry—measurement of the skull

Professionals often are called upon to compare not only the bones and anatomical features but also the contours and proportions of skulls and long bones. Observations must be translated into objective measurements, and relations between measurements may suggest the period of time in which the individual lived.

In order to take anthropometric measurements on bones one must learn the proper positions of the bones and points, or anthropometric landmarks, from which measurements are made.

The Frankfort Horizontal (Plane) (FH) is a plane passing through three points of the right and left porion and the left orbitale. The skull usually is oriented in this plane when drawings, photographs, or illustrations are to be made for comparative or illustrative purposes. When the eyes are fixed on the horizon, the skull normally is in a position so that all three points used to determine the FH are in the horizontal plane. First proposed at the Craniometric Congress held in Munich, Germany, in 1877, it later was ratified at the International Congress of Anthropologists in Frankfort, Germany, in 1884, hence the name.

There are two types of anthropometric points:

1. Unpaired: A single point that falls on the midsagittal plane (on the midline of the body). For example, there is only one point at the tip of the nose.
2. Paired: Two points that are equidistant on either side of the midsagittal plane. For example, if there is a point at the tip of the right ear, there must be a corresponding point at the same location on the left ear.

Measurements are taken between points or anatomical landmarks; thus the distance between two points can be given (e.g., the length of the skull is 190 mm). Indices express the ratio of the width to the length of an object—e.g., the Cranial Index expresses the ratio of the width of the skull to its length.

~~Literally~~ hundreds of anthropometric landmarks have been defined, but it is my intent here to give only those most commonly used. Landmarks are listed in many forms—alphabetical, by section of the body or skull, etc. I have found it very helpful for the student to start at the chin and work around the skull so that the landmarks will be in sequence.

The following section on craniometry has been arranged with the problems of the measurer in mind. The measurements needed to calculate an index are given (numbered) and are followed immediately by the index (lettered), which can be calculated from the measurements. Classification of the index units also are given.

Landmarks of the Skull Used for Taking Measurements and Calculating Indices

Figures 35–37 and tables 11 and 12 identify and define standard landmarks on the skull that are used by anthropologists for taking anthropometric measurements. Most of these landmarks refer to precise points on the surface of the skull, either external or internal. The measurements of the skull selected for description in this manual are standard measurements used by anthropologists and are listed below (Table 13). Standard indices derived from the measurements and described in this manual are listed in Table 14.

On the Cranial Vault (figures 38, 39)

1. Maximum length (spreading caliper). From glabella to opisthocranion (Figure 38). Place one end of the spreading caliper on glabella and support it with your finger. With the other end, locate the most posterior point on the midline (opisthocranion) and record length in mm. (Record all cranial vault measurements in mm.)
2. Maximum breadth (spreading caliper). From euryon to euryon (Figure 39). The maximum width or breath is determined instrumentally as both ends of the spreading caliper are moved back and forth on the sides of the skull above the supramastoid crest until the maximum width is located. Be careful of skulls with warped temporal bones. Sometimes the temporals have spread out, and width should not be taken from these.
3. Basion–bregma height (maximum height) (spreading caliper). From basion to bregma (Figure 38). Place skull on side or back and hold one

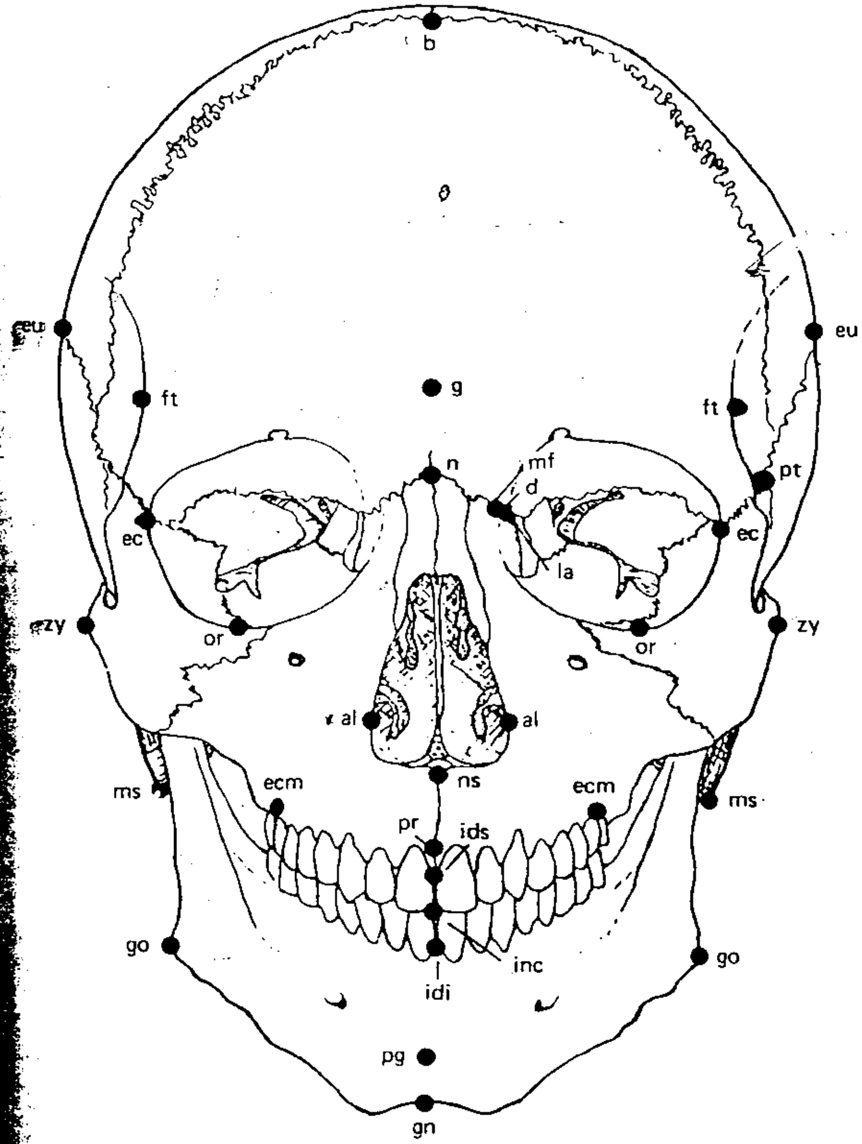


Figure 35. Selected anthropometric landmarks of the skull (frontal view).

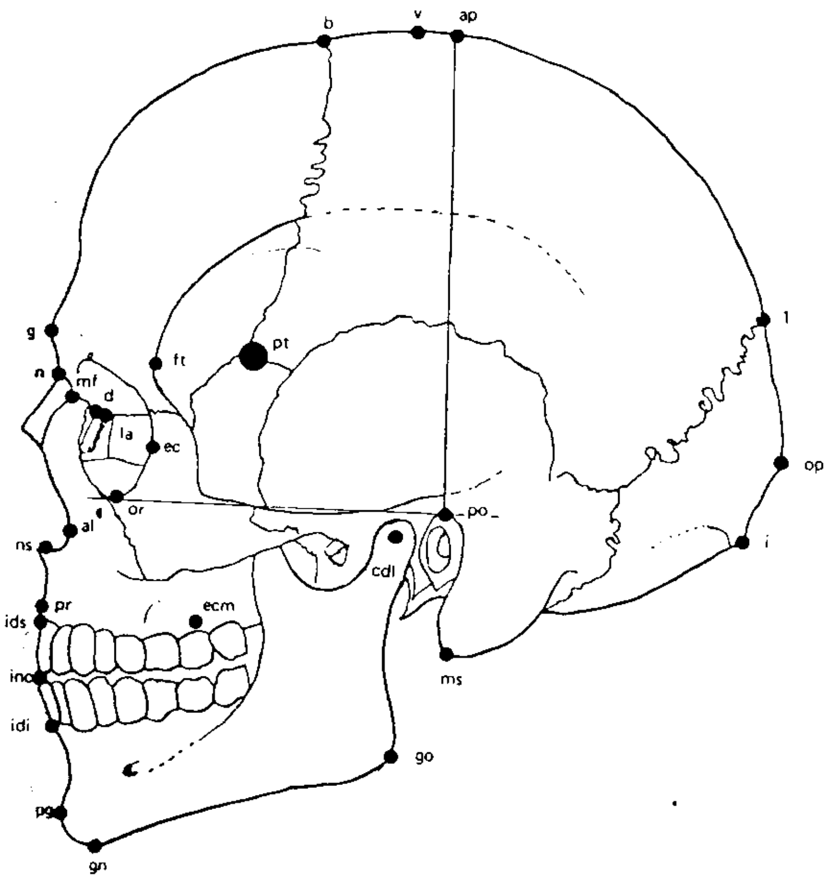


Figure 36. Selected anthropometric landmarks of the skull (lateral view).

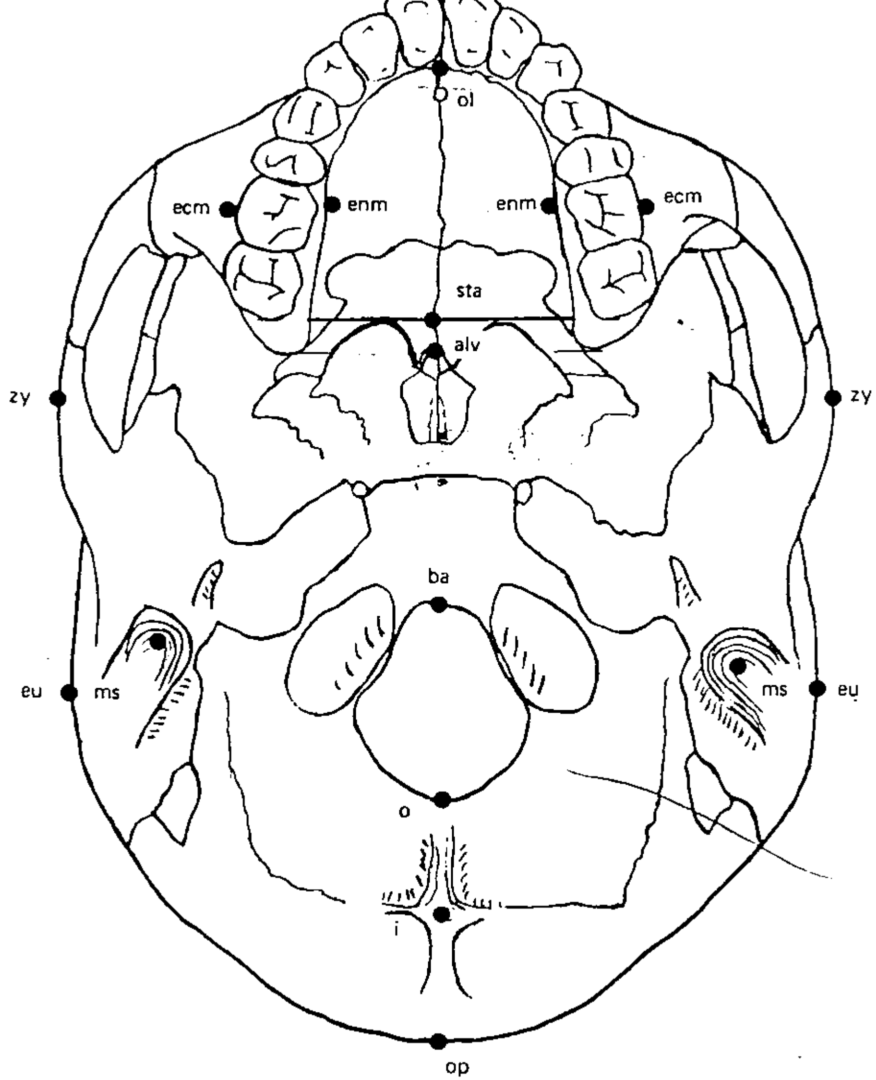


Figure 37. Selected anthropometric landmarks of the skull (base view).

TABLE 11.

Unpaired Craniometric Points on the Midsagittal Plane[a]

Facial Skeleton

Gnathion (gn)—The lowest median point on the lower border of the mandible.

Pogonion (pg)—The most anterior point in the midline on the chin.

Infradentale (idi) (the lower alveolar point)—The apex of the septum between the lower central incisors.

Incision (inc)—The incisal level of the upper central incisors.

Alveolare (ids) (infradentale superius)—The upper alveolar point; the apex of the septum between the upper central incisors. The lowest landmark for the measurement of facial height.

Prosthion (pr) (prealveolar point)—Has often been confused with alveolare. Prosthion is the most anterior point in the midline on the upper alveolar process.

Nasospinale (ns)—The point where a line drawn between the lower margins of the right and left nasal apertures is intersected by the MSP (midsagittal plane). NS is the lowest landmark for the measurement of nasal height.

Nasion (n)—Intersection of the nasofrontal suture with the midsagittal plane. Nasion is the uppermost landmark for the measure of facial height.

Braincase

Glabella (g)—The most forward projecting point in the midline of the forehead at the level of the supra-orbital ridges and above the nasofrontal suture.

Bregma (b)—The intersection of the coronal and sagittal sutures, in the midline.

Vertex (v)—The highest point in the midsagittal contour, as seen from norma lateralis (the lateral view in the Frankfort Horizontal), when the cranium is in the FH.

Apex (ap)—The point where a perpendicular line drawn to the FH through porion (with the skull in the FH) intersects the midsagittal contour.

Lambda (l)—The intersection of the sagittal and lambdoidal sutures in the midline.

Opisthocranion (op)—The most posterior point on the skull not on the external occipital protuberance. It is the posterior end point of maximum cranial length measured from glabella. It is thus not a fixed point but is instrumentally determined.

Inion (i)—A point at the base of the external occipital protuberance. It is the intersection of the MSP with a line drawn tangent to the uppermost convexity of the right and left superior nuchal line.

Opisthion (o)—The midpoint of the posterior margin of the foramen magnum.

Basion (ba)—The midpoint of the anterior margin of the foramen magnum most distant from the bregma. It is used to measure the height of the skull.

Endobasion (endoba)—The most posterior point of the anterior border of the foramen magnum on the border or contour of the foramen. It is thus placed a bit behind and internal to basion. In this way it gives the maximum basinasal and basiprosthion dimensions. (Not shown on figures.)

TABLE 11. (Continued)

Unpaired Craniometric Points on the Midsagittal Plane[a]

Hard Palate

Alveolon (alv)—A point on the hard palate where a line drawn through the termini of the alveolar ridges crosses the median line.

Staphylion (sta)—The point in the midline of the back of the hard palate (interpalatal suture) where it is crossed by a line drawn tangent to the curves of the posterior margin of the palate.

Orale (ol)—A point on the hard palate where the line drawn tangent to the curves in the alveolar margin back of the two medial incisor teeth crosses the MSP. It is on the opposite side of the bone from the alveolare.

[a]The midsagittal plane commonly is referred to as the MSP.

TABLE 12.

Paired Craniometric Points Lateral to the Midsagittal Plane

Euryon (eu)—The two points on the opposite sides of the skull that form the termini of the lines of greatest breadth, i.e., the most widely separated points on the two sides of the skull. The two points are determined instrumentally.

Porion (po)—The uppermost lateral point in the margin of the external auditory meatus. The right and left portion with the left orbitale define the FH.

Mastoidale (ms)—The lowest point on the mastoid process.

Dacryon (d)—The point on the medial wall of the orbit at the junction of the lacrimomaxillary suture and the frontal bone.

Lacrimale (la)—The point of intersection of the posterior lacrimal crest with the frontolacrimal suture.

Maxillofrontale (mf)—The point of intersection of the anterior lacrimal crest (medial edge of eye orbit), or the crest extended, with the frontomaxillary suture.

Alare (al)—The instrumentally determined most lateral point on the nasal aperture taken perpendicular to the nasal height.

Orbitale (or)—The lowest point in the margin of the orbit; one of the points used in defining the FH.

Zygion (zy)—The most lateral point of the zygomatic arch; a point determined instrumentally.

Ectoconchion (ec)—The point where the orbital length line, parallel to the upper border, meets the outer rim. Ectoconchion is the point of maximum breadth on the lateral wall of the eye orbit.

Ectomolare (ecm)—The most lateral point on the outer surface of the alveolar margins, usually opposite the middle of the upper second molar tooth. Used in taking the maxillary breadth.

Pterion (pt)—This is a region, rather than a point, and designates the upper end of the greater wing of the sphenoid, with the bordering bones, frontal, parietal, and temporal.

TABLE 12. (Continued)

Paired Craniometric Points Lateral to the Midsagittal Plane

Endomolare (enm)—The most medial point on the inner surface of the alveolar ridge opposite the middle of the second upper molar tooth; used in taking the palatal breadths.

Condylion laterale (cdl)—The most lateral point on the condyle of the mandible.

Gonion (go)—The midpoint of the angle of the mandible between body and ramus. In practice this is difficult to determine in jaws with a rounded angle. Draw a line tangent to the posterior border of the ascending ramus. Draw another tangent to the body of the mandible. Bisecting this angle will give the point gonion on the lateral surface of the mandible.

Frontotemporale (ft)—The most medial point on the incurve of the temporal ridge. The points lie on the frontal bones just above the zygomaticofrontal suture.

TABLE 13.

Described Cranial Measurements and Page Numbers for Discussion.

No.	Measurement	Page
1	Maximum cranial length	62
2	Maximum cranial breadth	62
3	Basion–bregma height (maximum height)	62
4	Porion–bregma height	72
5	Basion–porion height	73
6	Auricular height	74
7	Minimum frontal breadth	74
8	Total facial height	74
9	Upper facial height	75
10	Facial width or bizygomatic breadth	75
11	Nasal height	75
12	Nasal breadth	76
13	Orbital height	76
14	Orbital breadth	76
15	Maxilloalveolar length	77
16	Maxilloalveolar breadth	77
17	Palatal length	79
18	Palatal breadth	79
19	Bicondylar breadth	79
20	Bigonial breadth	79
21	Height of ascending ramus	79
22	Minimum breadth of ascending ramus	79
23	Height of mandibular symphysis	79

TABLE 14.

Described Cranial Indices and Page Numbers for Discussion

Letter	Index	Page
A	Cranial Index (CI)	69
B	Cranial Module	70
C	Cranial Length–Height Index	70
D	Cranial Breadth–Height Index	71
E_1	Mean Height Index	72
E_2	Mean Basion–Height Index	72
F	Mean Porion–Height Index	73
G	Flatness of the Cranial Base Index	74
H	Frontoparietal Index	74
I	Total Facial Index	75
J	Upper Facial Index	75
K	Nasal Index	76
L	Orbital Index	77
M	Maxilloalveolar Index	78
N	Palatal Index	79

end of caliper on basion. Place other end on bregma. If bregma is depressed (the sutures are much below the exterior surface of the vault), take the reading from the surface and not in the depression.

These three measurements can be used to calculate five indices for comparison ~~of size and~~ shape.

A. Cranial Index (CI) (The term Cephalic Index refers to measurements of the living): a numerical device for expressing the ratio of the breadth of the skull to the length (in percent). A skull whose breadth is the same as its length would have a CI of 100.00.

$$\text{Cranial Index} = \frac{\text{maximum cranial breadth} \times 100}{\text{maximum cranial length}}$$

$$\boxed{\text{Example}}\ \text{CI} = \frac{147 \times 100}{172} = \frac{14700.00}{172} = 85.47$$

Range:

Dolichocrany—X–74.99—narrow or long headed
Mesocrany—75.00–79.99—average or medium
Brachycrany—80.00–84.99—broad or round headed
Hyperbrachycrany—85.00–X—very broad headed

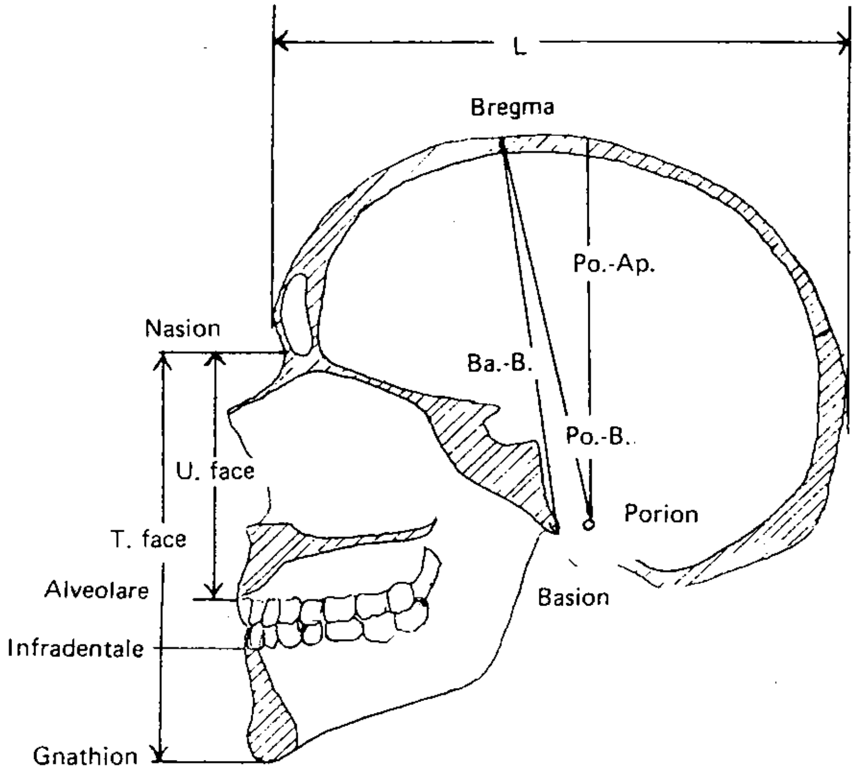


Figure 38. Craniometric points (lateral view).

In general, when skulls are studied from an evolutionary point of view, man's skull has become more brachycranic. Early fossil men usually have dolichocranic or long heads.

B. Cranial Module: provides an approximate numerical value for the size of the skull.

$$\text{Cranial Module} = \frac{\text{length} + \text{breadth} + \text{height}}{3}$$

C. Cranial Length–Height Index: expresses the ratio of height to length of a skull (in percent) (see Index E).

$$\text{Length–Height Index} = \frac{\text{basion–bregma height} \times 100}{\text{maximum length}}$$

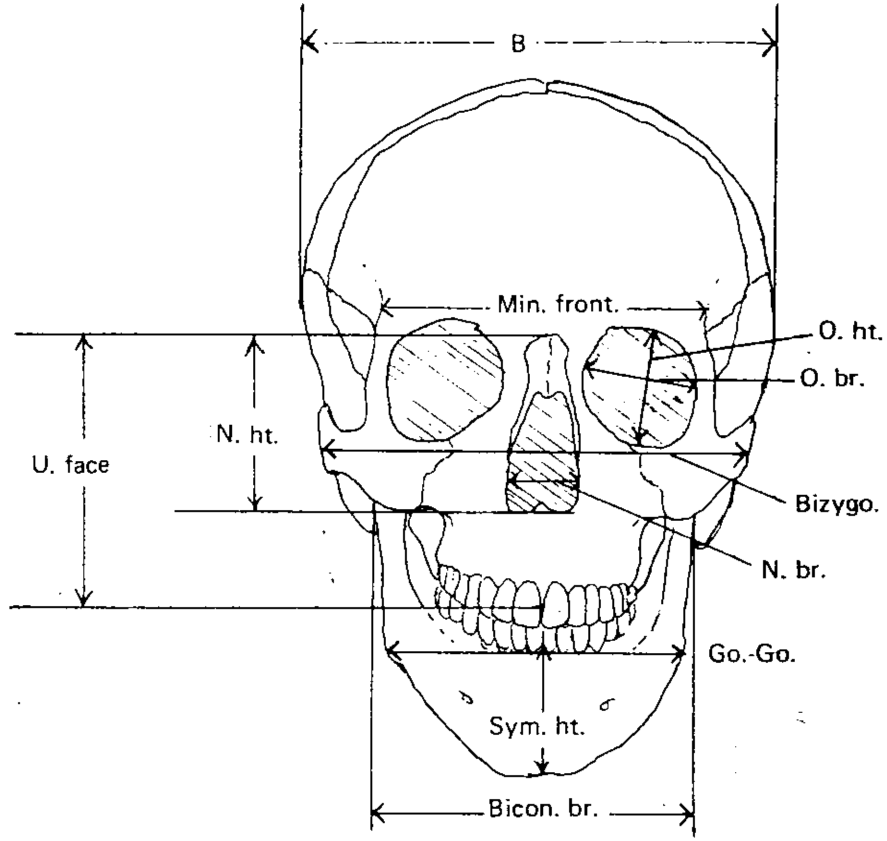


Figure 39. Craniometric points (frontal view).

Range (after Martin 1928):
- Chamaecrany—X–69.99—low skull
- Orthocrany—70.00–74.99—average or medium
- Hypsicrany—75.00–X—high skull

D. Cranial Breadth–Height Index: expresses the ratio of height to breadth of a skull (in percent) (see Index E).

$$\text{Breadth–Height Index} = \frac{\text{basion–bregma height} \times 100}{\text{maximum breadth}}$$

Range (after Martin 1928, who gives Broca's divisions as follows):
Tapeinocrany—X–91.99—low skull
Metriocrany—92.00–97.99—average or medium
Acrocrany—98.00–X—high skull

E_1. Mean Height Index: Stewart (1940) proposed the use of a Mean Height Index to replace both the Length–Height and Breadth–Height indices because it seemed to be a more sensitive indicator of anatomical change in the skull. Stewart included this measurement in Hrdlička's (1952) *Practical Anthropometry* and suggested the formula and range.

$$E_1 \text{ Mean Height Index} = \frac{\text{basion–bregma height} \times 100}{\text{mean of cranial length} + \text{breadth}}$$

$$\boxed{\text{Example}} \quad \frac{135 \times 100}{\frac{172 + 147}{2}} = \frac{13500.00}{159.5} = 84.01$$

Range (after Hrdlička is 1952 divisions):
Low—X–80.49
Medium—80.50–83.49
High—83.50–X

E_2. Mean Basion–Height Index: this is equivalent to the Mean Height Index but has been given a new name and new classificatory divisions have been suggested.

$$\text{Mean Basion–Height Index} = \frac{\text{basion–bregma height} \times 100}{\frac{\text{cranial length} + \text{breadth}}{2}}$$

New range (after Stewart 1965:363):
Low—X–78.99
Medium—79.00–85.99
High—86.00–X

In an important article Stewart (1965) draws attention to the fact that the base of the skull often is damaged or missing and thus eliminates much valuable data. He suggests that the following indices be used.

In order to calculate the second of Stewart's indices (Mean Porion–Height Index), the following measurement is necessary:

4. Porion–bregma height (head spanner). From porion to bregma (Figure 38). Place the two ear rods in the external auditory meatus on the right and left porions and the end of the calibrated bar on bregma. Read porion–bregma height directly from the calibrated bar.

F. Mean Porion–Height Index: compares the height of the skull from porion with the mean of the length plus the breadth. This measurement can be obtained when the face and the base of the skull are missing and only the cranial vault remains.

$$\text{Mean Porion–Height Index} = \frac{\text{porion–bregma} \times 100}{\frac{\text{cranial length} + \text{breadth}}{2}}$$

Range (after Stewart 1965:364):
Low—X–66.99
Medium—67.00–71.99
High—72.00–X

Note: Stewart states that when more comparative data are available, the above tentative classification may have to be revised.

Another effective index for classification of skulls according to cranial height has been proposed by Neumann (1942). In addition to the measurements already given, the following measurement is necessary to calculate the Index of Flatness of the Cranial Base.

5. Basion–porion height (coordinate caliper). From basion to porion (Figure 40). Place the ends of the sliding caliper on the right and left

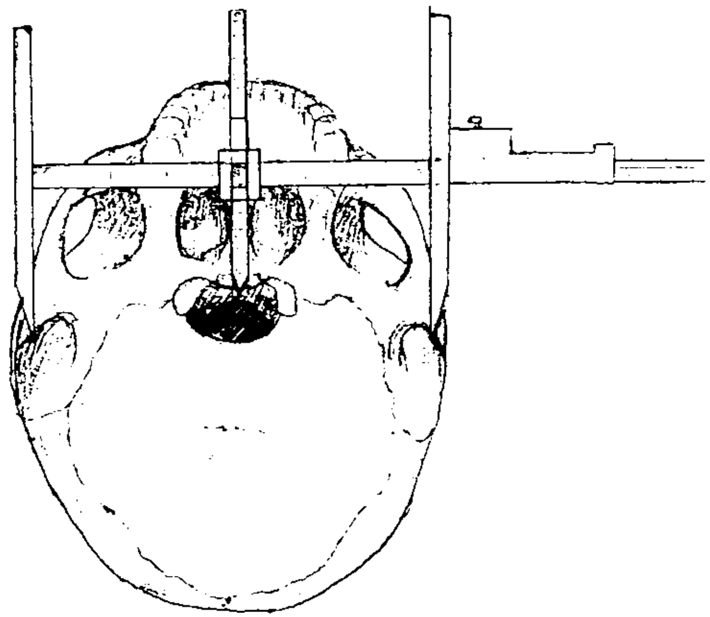


Figure 40. Position of the coordinate caliper to take basion–porion height.

porion. Move the coordinate attachment until it is over basion and read basion–porion height from the calibrated bar when the tip of the bar is placed on basion.

G. Index of Flatness of the Cranial Base: according to Neumann (1942), cranial height has two components: basion–porion and porion–bregma heights. He feels that crania with low vaults are mainly the result of flattening of the cranial base, i.e., a short basion–portion distance.

$$\text{Index of Flatness of the Cranial Base} = \frac{\text{basion–porion height} \times 100}{\text{basion–bregma height}}$$

Range (none proposed, but Neumann sample is):
- Low—average around 13.70 (Aleut, Apache)
- High—average around 18.40 (Ohio series)

6. Auricular height (head spanner). From porion to the apex (Figure 38). The head spanner has a device for orientation in the Frankfort Horizontal. The two horizontal pieces fit into the ear openings (porion), and when the attachment is placed on the left orbitale, the auricular height is read directly when the calibrated bar is placed at the apex. It should be noted that this measurement depends on the presence of the face to locate the left orbitale. Porion–bregma height is similar to this measurement and does not require the presence of the face.
7. Minimum frontal breadth (spreading or sliding caliper). From frontotemporale to frontotemporale (Figure 39). This is measured on the temporal line and at the point where they are closest together, i.e., the minimum distance between the temporal crests on the frontal bone.

H. Fronto–Parietal Index: expresses the relation between the minimum breadth of the frontal bone and the maximum breadth of the vault.

$$\text{Fronto–Parietal Index} = \frac{\text{minimum frontal breadth} \times 100}{\text{maximum cranial breadth}}$$

Range:
- Stenometopic—X–65.99—narrow
- Metriometopic—66.00–69.99—average or medium
- Eurymetopic—70.00–X—broad

On the Facial Skeleton

Heights

8. Total facial height (sliding caliper). From nasion to gnathion (Figure 38). With teeth occluded, place fixed limb of caliper at nasion and movable end on gnathion. This gives the height of the complete face.

9. Upper facial height (sliding caliper). From nasion to alveolare (Figure 38). This gives the height of the face excluding the teeth and the mandible. It is used when the mandible is missing.

Widths

10. Facial width or bizygomatic breadth (spreading or sliding caliper). From zygion to zygion (Figure 39); the greatest breadth between the zygomatic arches.

    These three measurements can be used to determine the size of the face. Two indices express the overall relation of height to breadth of the face.

I. Total Facial Index: a numerical expression of the ratio of the height to the breadth of the face including the teeth.

$$\text{Total Facial Index} = \frac{\text{total facial height} \times 100}{\text{bizygomatic breadth}}$$

Range:
- Hypereuryprosopy—X–79.99—very broad face
- Euryprosopy—80.00–84.99—broad face
- Mesoprosopy—85.00–89.99—average or medium
- Leptoprosopy—90.00–94.99—slender or narrow face
- Hyperleptoprosopy—95.00–X—very slender or narrow face

J. Upper Facial Index: gives a numerical expression of the height to breadth of the face that does not include the mandible teeth.

$$\text{Upper Facial Index} = \frac{\text{upper facial height} \times 100}{\text{bizygomatic breadth}}$$

Range (after Martin's 1928 divisions):
- Hypereuryeny—X–44.99—very wide or broad face
- Euryeny—45.00–49.99—wide or broad face
- Meseny—50.00–54.99—average or medium
- Lepteny—55.00–59.99—slender or narrow face
- Hyperlepteny—60.00–X—very slender or narrow face

The Nose (Figure 41)

11. Nasal height (sliding caliper). From nasion to nasospinale (Figure 41). Place fixed point of caliper at nasion and with movable point obtain the mean of the lowest points of the right and left nasal margins (nasospinale).

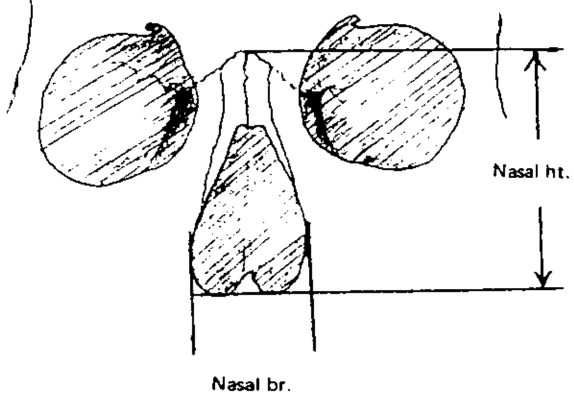


Figure 41. Landmarks for measuring nasal height and breadth.

12. Nasal breadth (sliding caliper). From alare to alare (Figure 41). The maximum breadth of the nasal cavity. Measured at a right angle to the height.

K. Nasal Index: a numerical method of expressing the relation of breadth to height of the anterior nasal aperture.

$$\text{Nasal Index} = \frac{\text{nasal breadth} \times 100}{\text{nasal height}}$$

Range:
- Leptorrhiny—X–47.99—narrow nasal aperture
- Mesorrhiny—48.00–52.99—average or medium
- Platyrrhiny—53.00–X—broad or wide nasal aperture

The Orbits

13. Orbital height (sliding caliper). The maximum height from the upper to the lower orbital borders perpendicular to the horizontal axis of the orbit and using the middle of the inferior border as a fixed point (Figure 42). Either or both orbits may be measured, but the left is standard.

14. Orbital breadth (width) (sliding caliper). From maxillofrontale to ectoconchion (Figure 42). The maximum distance of the orbit from maxillofrontale to the middle of the lateral orbital border (ectoconchion). Measurement also can be taken from dacryon or lacrimale, but I prefer maxillofrontale since this is present most often. Since

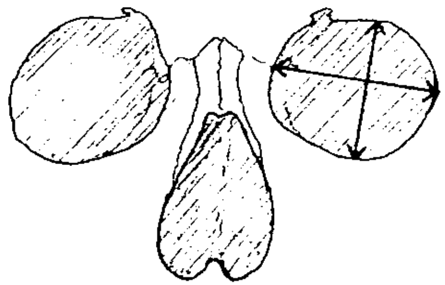


Figure 42. Landmarks for measuring orbit height and breadth.

bones of the medial wall of the eye orbit are quite fragile, dacryon and lacrimale often are missing in archaeological specimens. To locate maxillofrontale, extend the medial edge of the eye orbit with a pencil line until the line crosses the frontomaxillary suture.

L. Orbital Index: expresses the relation of height to breadth.

$$\text{Orbital Index} = \frac{\text{orbital height} \times 100}{\text{orbital breadth}}$$

Range:
- Chamaeconchy—X–82.99—wide orbits
- Mesoconchy—83.00–89.99—average or medium
- Hypsiconchy—89.00–X—narrow orbits

The Palate

15. Maxilloalveolar length (palatal length) (sliding or hinge caliper). From prosthion to alveolon (Figure 43). On a skull with protruding teeth it is difficult to take this measurement with a sliding caliper. Place one end of the caliper on prosthion and the other on a straight wire, knitting needle, or wooden rod placed across the posterior edges of the alveolar processes (alveolon) of the two sides.

16. Maxilloalveolar breadth (palatal breadth) (sliding or hinge caliper). From ectomolare to ectomolare (biectomolare) (Figure 43). The distance between the external surfaces of the alveolar border, usually opposite the second molar teeth. If there are any exotoses (bony growths projecting outward) on the border, they are to be avoided by placing the ends of the caliper in an unaffected area.

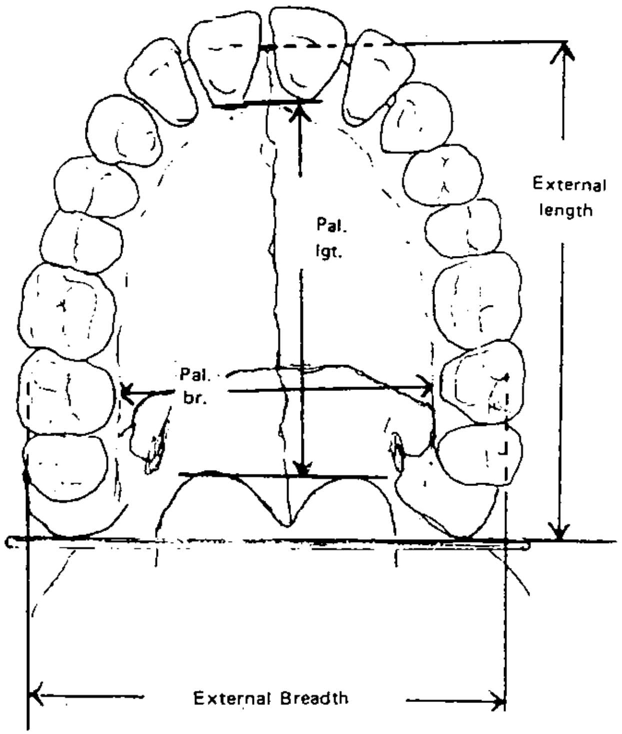


Figure 43. Landmarks for measuring palate length and breadth.

M. Maxilloalveolar Index: numerical ratio of the external measurements of the palate. Note that this is one of the few indices in which the smaller number is divided into the larger, giving an index of over 100.

$$\text{Maxilloalveolar Index} = \frac{\text{maxilloalveolar breadth} \times 100}{\text{maxilloalveolar length}}$$

Range:
Dolichurany—X–109.99—long or narrow palate
Mesurany—110.00–114.99—average or medium
Brachyurany—115.00–X—broad palate

Internal Measurements

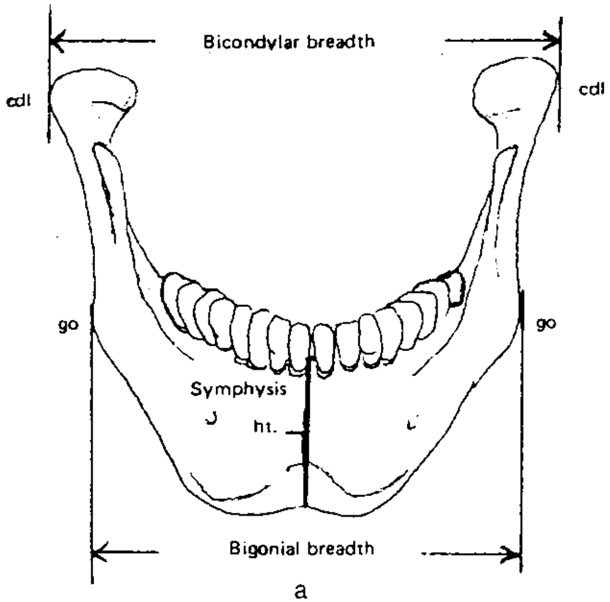
17. Palatal length (sliding caliper). From orale to staphylion (Figure 43). From the median point of a line tangent to the posterior alveolar border of the median incisors (orale) to the median point of a transverse line connecting the most anterior points of the notches in the posterior border of the palate.
18. Palatal breadth (sliding calipers). From endomolare to endomolare (biendomolare) (Figure 43). The greatest transverse breadth between the inner limits of the alveolar arch opposite the second molar teeth.

N. Palatal Index: numerical ratio of the internal measurements of the palate.

$$\text{Palatal Index} = \frac{\text{maximum palatal breadth} \times 100}{\text{maximum palatal length}}$$

Range:
Leptostaphyline—X–79.99—narrow palate
Mesostaphyline—80.00–84.99—average or medium
Brachystaphyline—85.00–X—broad palate

19. Bicondylar breadth (Figure 44a) (sliding caliper). From condylion to condylion (lateral). The maximum distance between the lateral surfaces of the condyles.
20. Bigonial breadth (Figure 44a) (sliding caliper). From gonion to gonion. The maximum distance between the external surfaces of the gonial angles.
21. Height (length) of ascending ramus (Figure 44b) (sliding caliper). From gonion to the uppermost part of the condyle. Locate gonion by bisecting the angles formed by prolonged lines drawn on the inferior and posterior borders of the bone and mark its location. Place fixed end of caliper on top of the condyles and bring movable end to gonion.
22. Minimum breadth of ascending ramus (Figure 44b) (sliding caliper). Minimum distance between the anterior and posterior borders of the ascending ramus. Can be taken on either right or left, but left is standard for comparison.
23. Height of mandibular symphysis (Figure 44a) (sliding caliper). From gnathion to infradentale (Figure 44a). Height in the midline from lowest point (gnathion) to the tip of bone between the lower central incisors (infradentale).



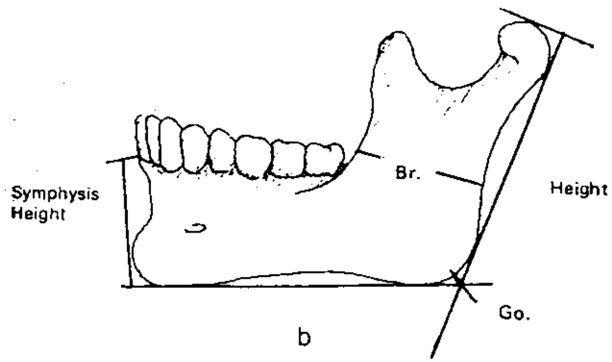


Figure 44. Landmarks for measuring the mandible: a, frontal view; b, lateral view.

SEX ESTIMATION

The skull probably is the second best area of the skeleton to use for determining sex. Estimation of sex is based on the generalization that the male is more robust, rugged, and muscle marked than the female. Absolute differences seldom exist, and many intermediate forms are found, but distinguishing characteristics are as follows:

A. Face (Figure 45a)
   1. Supraorbital ridges are more prominent in males than in females.
   2. Upper edges of the eye orbits are sharp in females, blunt in males.
   3. The palate is larger in males.
   4. Teeth are larger in males.

B. Mandible (Figure 45b)
   1. The chin is more square in males and rounded with a point in the midline in females.
   2. Teeth are larger in males.

C. Vault (Figure 45c, d)
   1. The female skull is smaller, smoother, and more gracile. The female skull retains the childhood characteristics of frontal and parietal bossing into adulthood (Keen 1950).
   2. Muscle ridges, especially on the occipital bone, are larger in males (nuchal crests).
   3. The posterior end of the zygomatic process extends as a crest farther in males, often much past the external auditory meatus.
   4. Mastoid processes are larger in males.
   5. Frontal sinuses are larger in males.

The student should be familiar with the following articles that have continued to address the question of estimation of sex using characteristic features of the skull (Angel 1982; Holland 1986; and Meindl *et al.* 1985). Of special interest is Holland's article (1986), which documents his attempts to use measurements of the base of the cranium to determine sex. He achieved a high degree of success with the formula he developed, and it is clear that more work will appear in the near future.

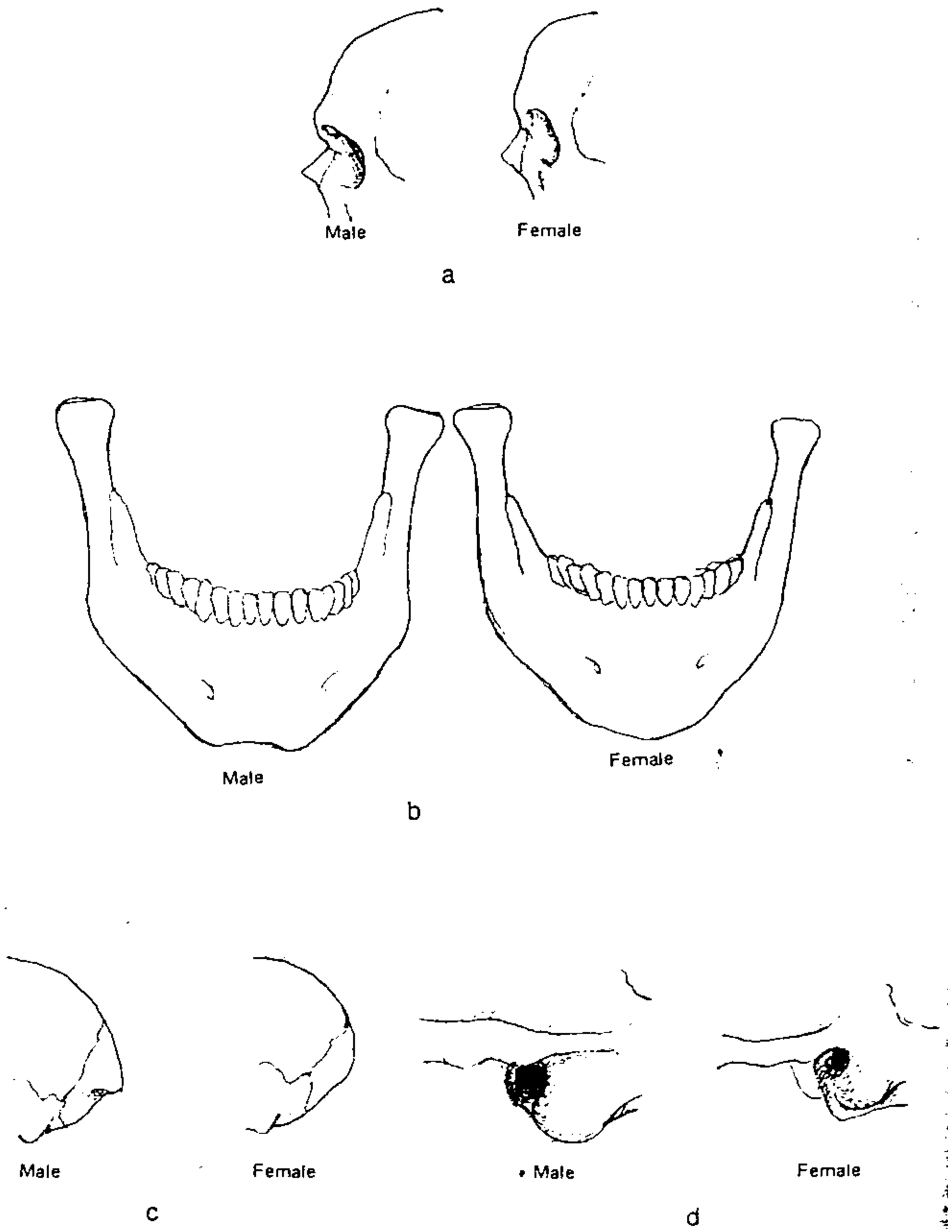


Figure 45. Distinguishing characteristics of the crania used to determine sex: a, brow ridge and forehead; b, the mandible; c, nuchal crest; d, the mastoid process.

RACE ESTIMATION

The skull is the only area of the skeleton from which an accurate estimation of racial origin may be obtained. Note that anterior femoral curvature has been studied (Stewart 1962) as a possible indicator of the racial background of an individual, but at present the few studies on femoral curvature have reported conflicting results and all of the studies are of small sample sizes.

Determinations of race from the skull mainly have been confined to the facial skeleton and have followed two major approaches: (*a*) morphological and anatomical variations of the bone structure and (*b*) anthropometric measurements (Giles and Elliot 1962).

Morphological and Anatomical Variations

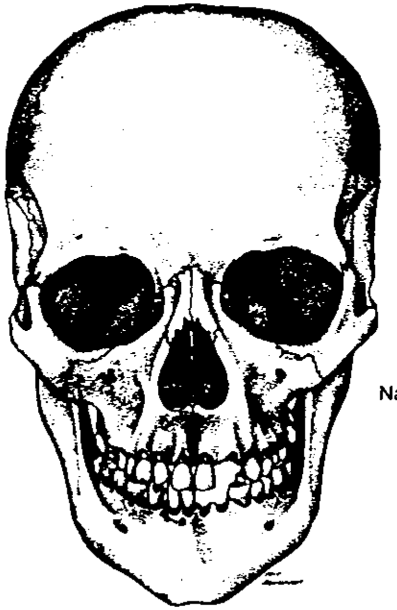
Much has been written on racial differences, and the reader should be aware of the problems, pitfalls, and cautions of attributing race to the skull (see Krogman 1962; Stewart 1979). The following morphological traits are general in nature and usually are readily apparent.

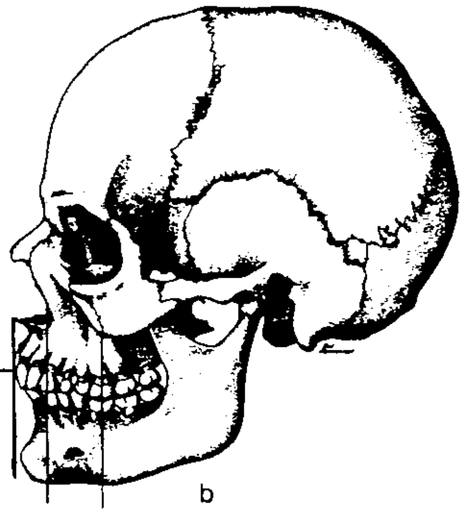
A careful observation of the following cranial illustrations—paired frontal and lateral views of a Caucasoid (white) skull (Figure 46a, b), a Negroid (black) skull (Figure 46c, d), and a Mongoloid (American Indian [Arikara]) skull (Figure 46e, f) will aid in developing techniques for estimating racial origins. Certain anatomical features are common to each race.

Caucasoid (Figure 46a, b)

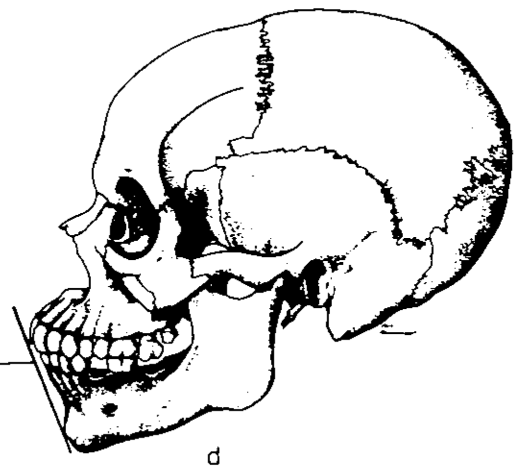
Nasal sill: Carefully observe the base of the nasal aperture. With your pencil or ballpoint pen resting against the bone of the maxilla just below the nasal opening, try to run the pencil or pen gently into the nasal opening. In Caucasoids there is usually a dam (nasal sill) that will stop the pen or pencil. In Negroid skulls there is no dam or nasal sill, and the pen easily will glide into the nasal aperture. Mongoloid skulls will range between these two extremes.

Retreating zygomatics: Hold the skull with the occipital region in your hand and the facial area up. Place a pencil across the nasal aperture. Now try to insert your index finger between the cheek (zygomatic) bones and the pencil. Caucasoids have a face that comes to a point along the midline and cheek bones that do not extend forward. This will allow you to insert your finger between the cheek bones and the pencil without knocking the pencil off. Mongoloids have a much flatter face (the cheek bones extending much further forward), and it is difficult to insert your finger between the pencil and the cheek bones on a Mongoloid skull without knocking the pencil off.


Caucasoid
Nasal sill
a


Flat (Orthognathous) face
Retreating zygomatics a ←→ b
b


Negroid
Nasal guttering
c


Prognathism
d

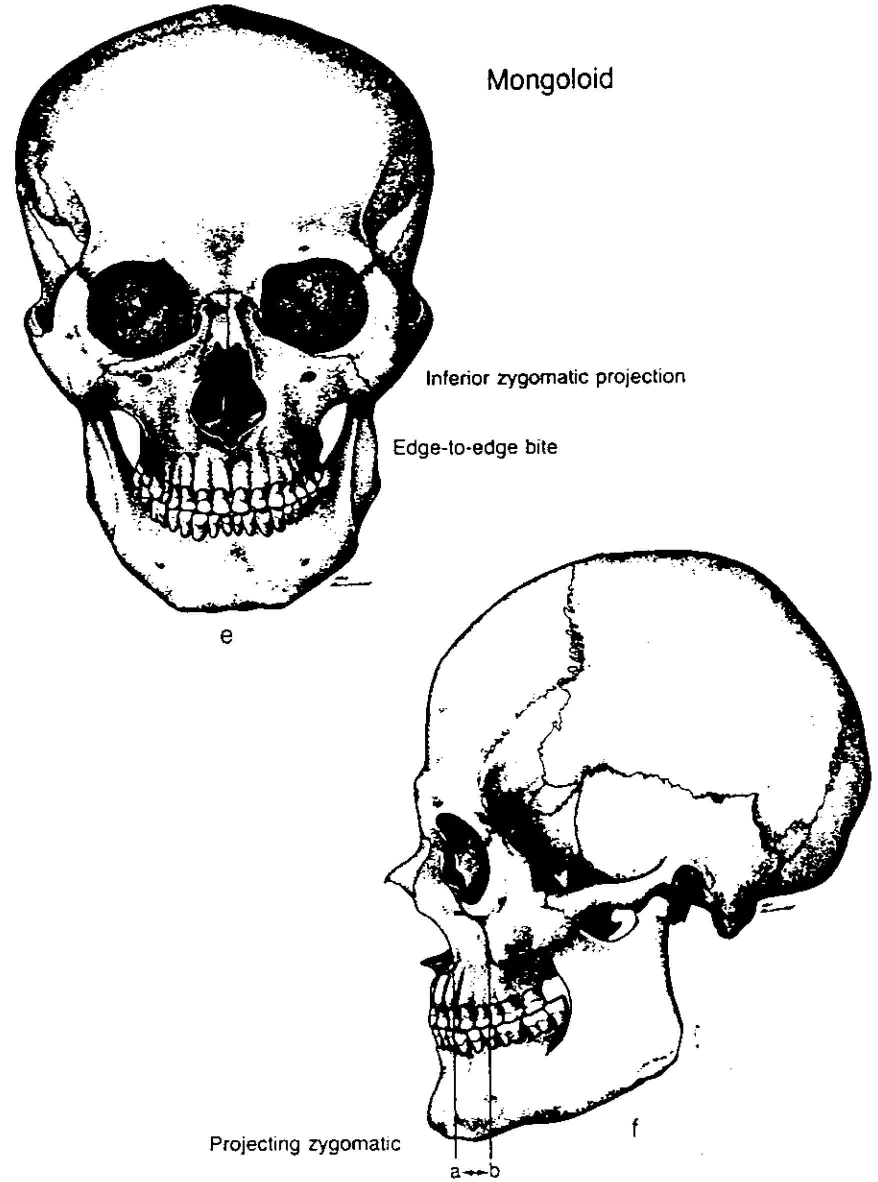


Figure 46. Anatomical features of the cranium useful for evaluating racial origin: a, frontal view of Caucasoid male skull; b, left lateral view of Caucasoid skull (note that distance between the retreating zygomatics, a and b, is greater than on the Mongoloid skull [see Figure 46f] ; c, frontal view of Negroid female skull; d, left lateral view of Negroid skull; e, frontal view of Mongoloid male skull; f, left lateral view of Mongoloid skull (note that distance between the projecting zygomatics, a and b, is less than on the Caucasoid skull [see Figure 46b]).

Little or no prognathism: Place one end of your pencil on or near the anterior nasal spine (on the midline of the skull) at the base of the nasal aperture. Lower the pencil toward the face so that the pencil will touch the chin. Caucasoids have a "flat" (orthognathous) face in the dental area along the midline. This is the opposite of the Negroid face, which exhibits protrusion of the mouth region, known as prognathism.

Other Caucasoid anatomical traits include:

- Long narrow face
- Narrow nasal opening
- Depressed nasal root (at nasion)
- Narrow high bridge nose

Negroid (Figure 46c, d)

Nasal guttering: The shape of the base of the nose has a gutter and lacks the nasal sill seen in Caucasoids.

Prognathism: Negroids are noted for alveolar prognathism, or an anterior protrusion, of the mouth region. A pencil or ballpoint pen placed with one end on the nasal spine (midline at base of nasal aperture) will not touch the chin (the teeth protrude too far forward).

Other Negroid anatomical traits include:

- Little or no nasal depression (at nasion)
- Rounded forehead
- Bregmatic depression
- Wide nasal opening
- A dense or "ivory texture" to the bone

Mongoloid (including American Indian) (Figure 46e, f)

Projecting zygomatics: Mongoloid skulls have a flat, moonlike face. This is caused partly by the fact that the cheek bone protrudes forward as in Caucasoid skulls. Hold the skull with the occipital region in your hand and the facial area up. Place a pencil or pen across the nasal aperture. Now try to insert your index finger between the pencil and the cheek bone. Since the cheek bones protrude in Mongoloids, you probably will not be able to get your finger between the cheek bones and pencil without knocking the pencil off.

Edge-to-edge bite: When you occlude the mandible and maxilla in most American Indian skulls, the incisor teeth will occlude edge to edge instead of presenting an overbite as usually found in Caucasoids or Negroids. If you find a mandible or maxilla with occlusal wear on the incisor teeth, you can be fairly certain that this individual is American Indian.

American Indians often had grit or dirt in their food, causing wear to

the enamel of the teeth. With an edge-to-edge bite in the incisor region, the occlusal surfaces of the incisor teeth often are worn.

Keep in mind that incisor teeth have single roots. When the tissue decays, incisor teeth can fall out of their sockets quite easily. After a skull is found, check immediately for any recently missing teeth. Root sockets with sharp, well-defined edges offer reliable clues to newly missing teeth.

Shovel-shaped incisors (see Chapter 4): In many Mongoloids the lingual (tongue) surface of the maxillary incisor teeth (especially the central incisors) will have an enamel extension on the edges, producing a tooth that is shovel shaped. In some cases the central incisors also may be rotated slightly toward the midline.

Additional Mongoloid anatomical traits include:

Inferior zygomatic projection. The zygomatic bones dip below the lower edge of the maxilla.

Nasal overgrowth. The nasal bones project forward beyond their junction with the frontal portion of the maxilla.

Anthropometric Measurements

One of the earlier discriminant functions used to assess the racial ancestry of a skull is that reported by Giles and Elliot (1962). The Giles and Elliot discriminant function, along with a worksheet devised by Giles, is reproduced in Figure 47. The Giles and Elliot method, when applied to American Indian samples, has been criticized by Birkby (1966) and Gill and Hughes (1979). Faced with problems in determining racial origins from skeletal remains in the northwestern Great Plains, Gill (1984) and his students at the University of Wyoming have developed an anthropometric method using three indices that results in a ninety-percent-correct classification. Gill generously has provided directions for using this technique, which is reproduced in the original worksheet format (Figure 48). Note that a sinometer is required (Figure 49). Figures 48 and 50 show the indices and landmarks used for this technique.

Specimen: ______ Date: ______ Measured by: ______

MEASUREMENT	MALE WHT/NEG	MALE WHT/IND	FEMALE WHT/NEG	FEMALE WHT/IND	SEX MEAS. NO. FACTOR
*1. Basion–Prosthion Ht. ___ x	+ 3.06 = ___	+ 0.10 = ___	+ 1.74 = ___	+ 3.05 = ___	1. ___ x − 1.00 = ___
*2. Glabello–Occip. Ln ___ x	+ 1.60 = ___	− 0.25 = ___	+ 1.28 = ___	− 1.04 = ___	2. ___ x + 1.16 = ___
3. Maximum Width ___ x	− 1.90 = ___	− 1.56 = ___	− 1.18 = ___	− 5.41 = ___	5. ___ x + 1.66 = ___
4. Basion–Bregma Ht. ___ x	− 1.79 = ___	+ 0.73 = ___	− 0.14 = ___	+ 4.29 = ___	6. ___ x + 3.98 = ___
*5. Basion–Nasion Ht ___ x	− 4.41 = ___	− 0.29 = ___	− 2.34 = ___	− 4.02 = ___	7. ___ x + 1.54 = ___
*6. Max Diam. Bi-zyg. ___ x	− 0.10 = ___	+ 1.75 = ___	+ 0.38 = ___	+ 5.62 = ___	TOTAL = ___
*7. Prosth.–Nasion Ht. ___ x	+ 2.59 = ___	− 0.16 = ___	− 0.01 = ___	− 1.00 = ___	MALE ___ + 891.12
8. Nasal Width ___ x	+ 10.56 = ___	− 0.84 = ___	+ 2.45 = ___	− 2.19 = ___	FEMALE ___ −
TOTALS					

*These measurements are used for calculating sex.

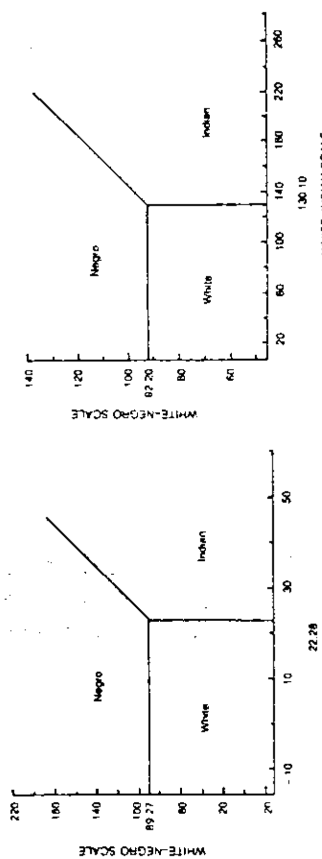


Figure 47. Giles and Elliot (1962) worksheet for race identification from cranial measurements.

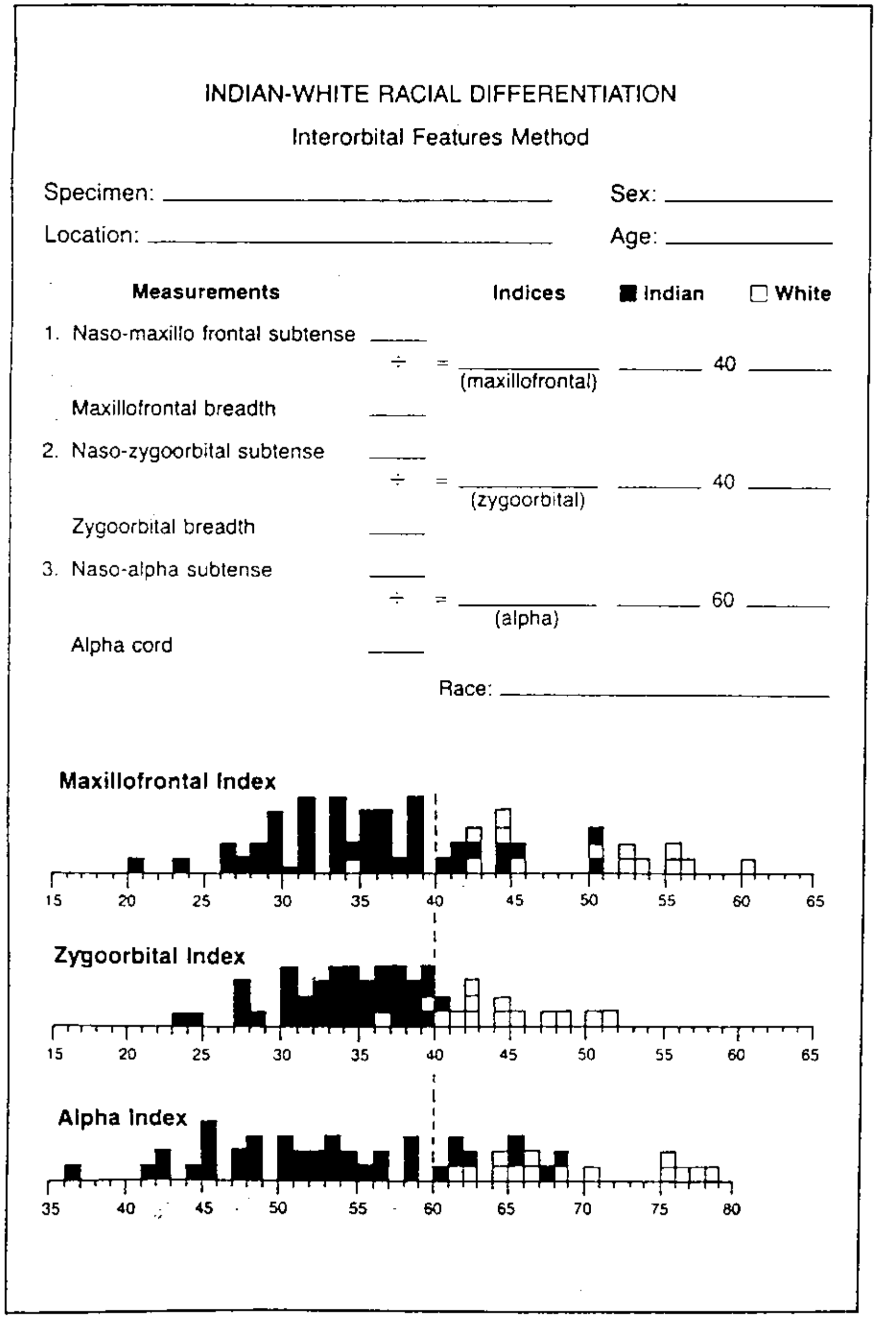


Figure 48. Indices for Indian–white racial differentiation (from Gill 1984).

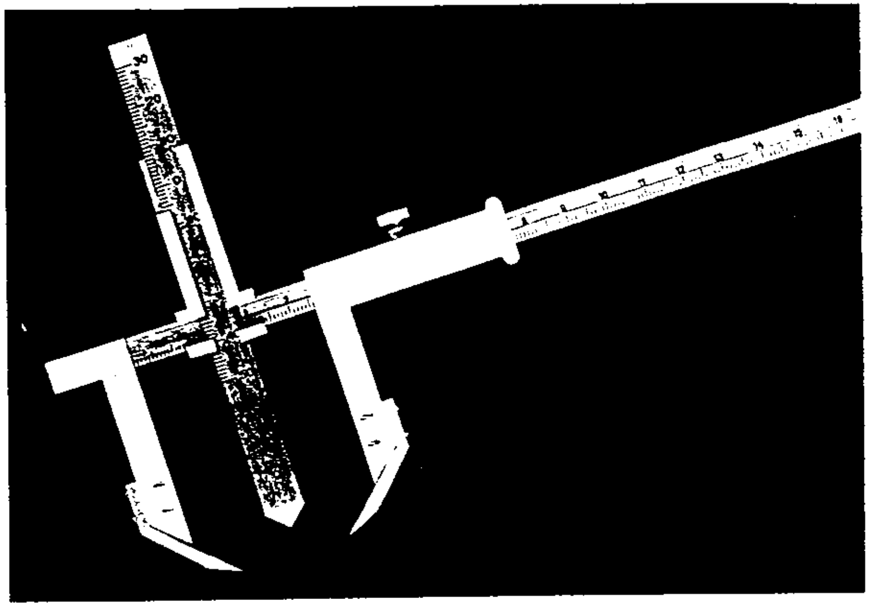
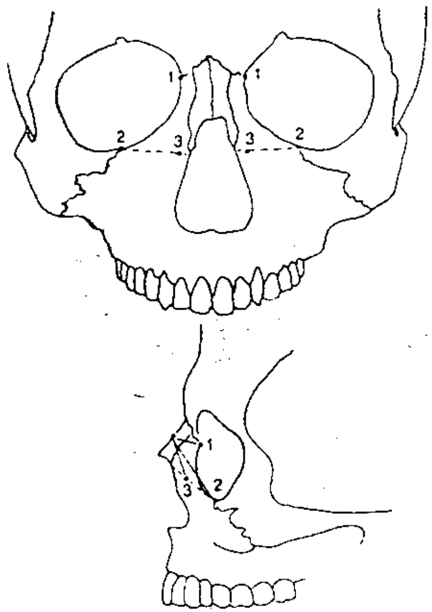


Figure 49. A sinometer (courtesy of G. Gill).



1 *Maxillofrontal breadth*—breadth between maxillofrontale left and right.
Maxillofrontale is defined by Bass (1971:60) as the intersection of the fronto-maxillary suture and "anterior lacrimal crest, or the crest extended (medial edge of the eye orbit)".
Naso-maxillofrontal subtense—subtense from the maxillofrontal points to the deepest point on the nasal bridge.

2 *Mid-orbital breadth*—the breadth between zygoorbitale left and right.
Zygoorbitale is defined by Howells as "the intersection of the orbital margin and the zygomaxillary suture" (Howells 1973:170). Occasionally the suture meanders along the orbital border; then its most mesial location is chosen as zygoorbitale.
Naso-zygoorbital subtense—subtense from the zygoorbital points to the deepest point along the nasal bridge.

3 *Alpha cord*
The point alpha is the deepest point on the maxilla, left and right, on a tangent run between the naso-maxillary suture where it meets the nasal aperture, and zygoorbitale.
To determine alpha, a straight line is pencilled connecting the above two points, then a straight edge is placed across the two points, and the skull is turned upwards until the profile of the straight edge and pencilled line are visible. The deepest point is easy to find and it is marked on the pencilled line. The deepest point usually coincides with the slight concavity from which the maxilla rises anteriorly to the nasal aperture. When the concavity forms a long shallow depression in profile and the deepest point is difficult to determine, then the mid-point along the pencilled line is chosen.
Naso-alpha subtense—subtense from the alpha points to the deepest point on the nasal bridge.

Figure 50. Landmarks for facial measurements used in racial differentiation (Gill 1984). Definitions for landmarks adapted from Hughes (1980).

3

POSTCRANIAL SKELETON

The postcranial skeleton includes all the bones below the skull. Since there are 29 (the hyoid is counted with the skull) bones in the skull, there should be 177 bones in the postcranial skeleton to account for the usual 206 bones in the adult human skeleton. Most of these are paired bones (i.e., bones having both right and left elements).

The following general list (Table 15) may help the student to better understand the distribution of bones in the postcranial skeleton.

BONES OF THE VERTEBRAL COLUMN

General Identification and Development

The vertebral column usually is composed of 33 segments (Figure 51). Sometimes one more or less may be found. The upper 24 (cervical, thoracic, and lumbar) segments are separate and are true or movable vertebrae. Of these, 12 articulate with ribs and 12 do not. The next 5 (sacral) vertebrae rapidly decrease in size and in adults are fused into a triangular bone, the sacrum, which along with the 2 innominates, comprise the pelvis. The next 4, or sometimes 5, are the coccygeal or tail vertebrae (coccyx). From head to tail, the number and names of the vertebrae are as follows:

	Type	Region	N
	Cervical	neck	7
	Thoracic	chest	12
	Lumbar	lower back	5
	Sacral	pelvis	5
	Coccygeal	"tail"	4
Total			33

Subadult Bones

Ossification of a vertebra takes place in cartilage from 3 primary centers (appearing from 7–20 weeks intrauterine) and 5 secondary centers (appearing about puberty).

At birth each typical vertebra consists of three bony parts—the centrum and the two halves of the arch (Figure 52a). Union (synosteosis) of the two halves of the arch takes place posteriorly during the first and third year

TABLE 15.

Bones of the Postcranial Skeleton

Bone	Number
Unpaired	
Vertebrae	
Cervical	7
Thoracic	12
Lumbar	5
Sacrum	1[a]
Coccyx	1[b]
Sternum	1[c]
Total	27
Paired	
Shoulder girdle[d]	
Scapula	2
Clavicle	2
Ribs	24
Upper extremities	
Humerus	2
Radius	2
Ulna	2
Carpus	16
Metacarpus	10
Phalanges	28
Total	88
Pelvic girdle[e]	
Hip bone	2
Lower extremities	
Femur	2
Patella	2
Tibia	2
Fibula	2
Tarsus	14
Metatarsus	10
Phalanges	28
Total	62
Total number of postcranial bones	177

[a]Usually 5 segments that fuse in adults.
[b]Usually 4 or 5 segments that may fuse in adults.
[c]Usually 3 segments that may fuse in adults.
[d]Includes sternum.
[e]Includes sacrum.

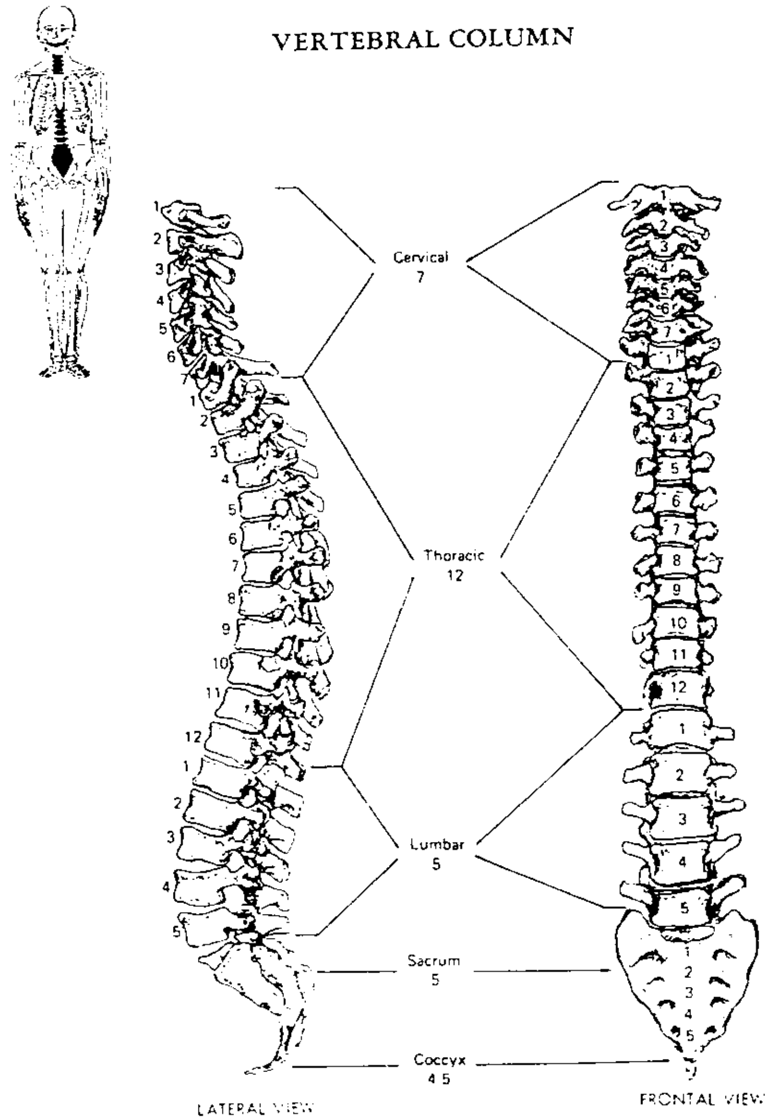


Figure 51. Lateral and frontal views of the vertebral column.

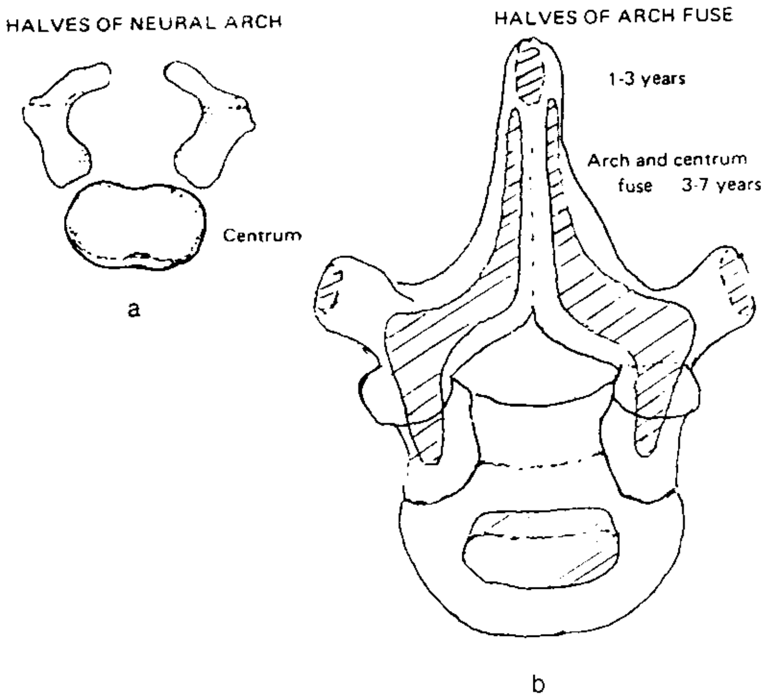


Figure 52. Primary fusion centers of the vertebrae: a, neonate vertebra; b, fusion centers.

(some say as late as the seventh year), and the arch and body fuse between the third and seventh year (Figure 52b). The vertebrae almost attain their full size by puberty, even though the epiphyses have not yet fused.

Secondary Centers

With the exception of some of the upper cervical vertebrae, all present at least five epiphyses—superior and inferior epiphyseal rings of the centrum, the tips of the spinous process, and both tips of the transverse processes (Figure 53a). These epiphyses appear about puberty and fuse between 17–25 years of age.

In the human skeleton the superior and inferior surfaces of the vertebral body form marginal epiphyseal rings, but they are complete plates in other mammals, e.g., dogs and sheep.

The surfaces of immature centra (Figure 53b) have a billowed appearance and resemble epiphyseal surfaces elsewhere in the skeleton, especially the symphyseal surface of the pelvis.

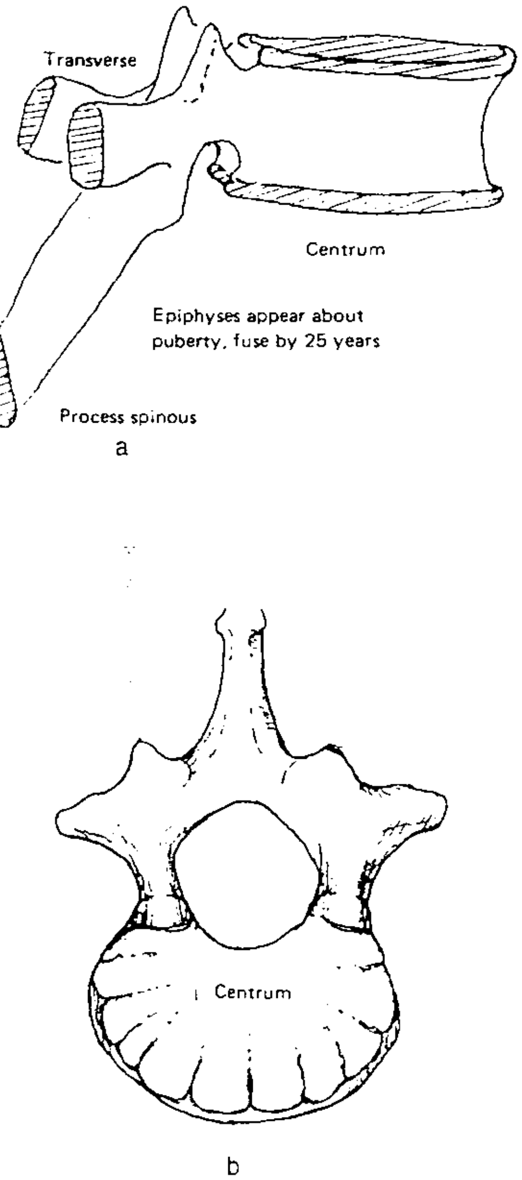


Figure 53. Ossification of the vertebrae: a, five secondary centers; b, billowed centrum of a subadult.

Adult Bones

The bones of each region have characteristic features that are particular to that segment of the spinal column, but every bone in the column has one or more distinguishing features of its own.

Most vertebrae are composed of four parts (Figure 54):

1. Body—weight-bearing portion (except for the first cervical vertebra, which has no body).
2. Vertebral arch—part that protects the spinal cord.
3. Spinous process and right and left transverse processes—for attachment of muscles.
4. Four articular processes; two superior (above) and two inferior (below)—for articulation with vertebrae above and below.

In the first 24 vertebrae the size of the body increases from head to tail to support the increased weight. When called on to reassemble the vertebrae of a disarticulated column, give first consideration to the relative massiveness of the bodies and later regard articular facets and inclination of articular processes. Above the sacrum all the body weight is supported on the vertebral column. Below the pelvis, weight is supported on two columns, the legs.

Variations do occur in the number of vertebrae. Whereas the number of cervical vertebrae is quite constant at seven, additional vertebrae can occur in both the thoracic and lumbar regions. Less common is a missing vertebra in the latter regions.

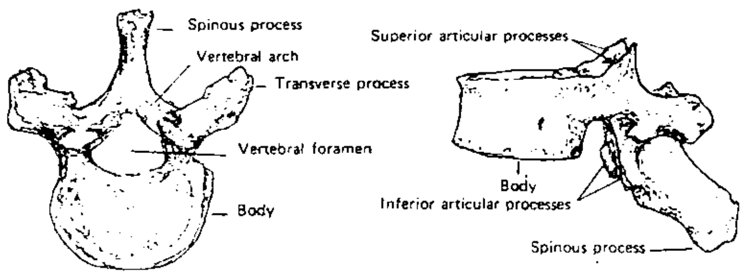


Figure 54. Characteristic features of an adult vertebra.

Cervical Vertebrae: 7 Unpaired, Irregular Bones (Figure 55)

It is through the cervical vertebrae that the skull articulates with the postcranial skeleton, and these vertebrae possess a high degree of flexibility. They are the smallest of the movable vertebrae. Mammals, with few exceptions, have seven.

Type	Region	N
Cervical	neck	7

Anatomical Characteristics of Importance in Identification

All have transverse foramina. A transverse foramen is found only in cervical vertebrae.

Cervical vertebrae are smaller in size when compared with the thoracic and lumbar vertebrae but increase in size from numbers 1 through 7.

The ventral (front) portion of the articular surface of the body of numbers 3–6 and the upper border of 7 are lower in the center than on the sides.

Bones of Similar Shape where Confusion May Arise

Thoracic and possibly lumbar vertebrae. These are larger and do not have transverse foramina.

Cervical Vertebrae of Special Interest

Number 1, the atlas

This is the only true vertebra that has no body or central mass of bone and no spinous process. It is merely a large ring upon which the skull rests.

Number 2, the axis or epistropheus

The second vertebra is identified easily because of the dens epistropheus that forms a pivot on which the atlas, carrying the head, rotates. The dens, sometimes known as the odontoid process (the displaced body of the atlas), has an articular facet on its ventral (front) surface for articulation with the atlas.

Number 7

A transitional vertebra situated at the junction of the cervical and thoracic regions, this presents characteristics of both regions:

1. It has the largest body of any cervical vertebra.
2. It has a flat or straight inferior (bottom) edge of the body.

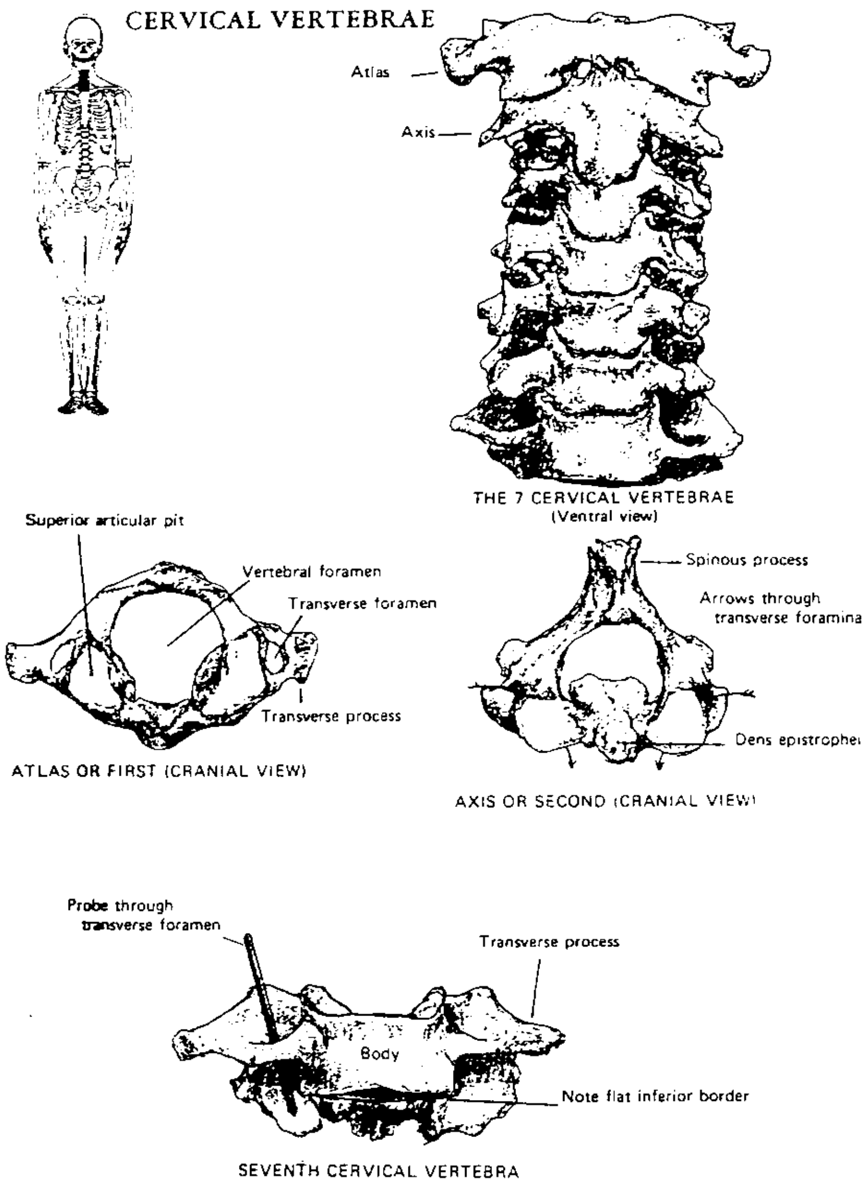


Figure 55. Characteristic features of the cervical vertebra.

Thoracic Vertebrae: 12 Unpaired, Irregular Bones (Figure 56)

The thoracic vertebrae support the ribs and help to compose the thorax.

Type	Region	N
Thoracic	chest (midback)	12

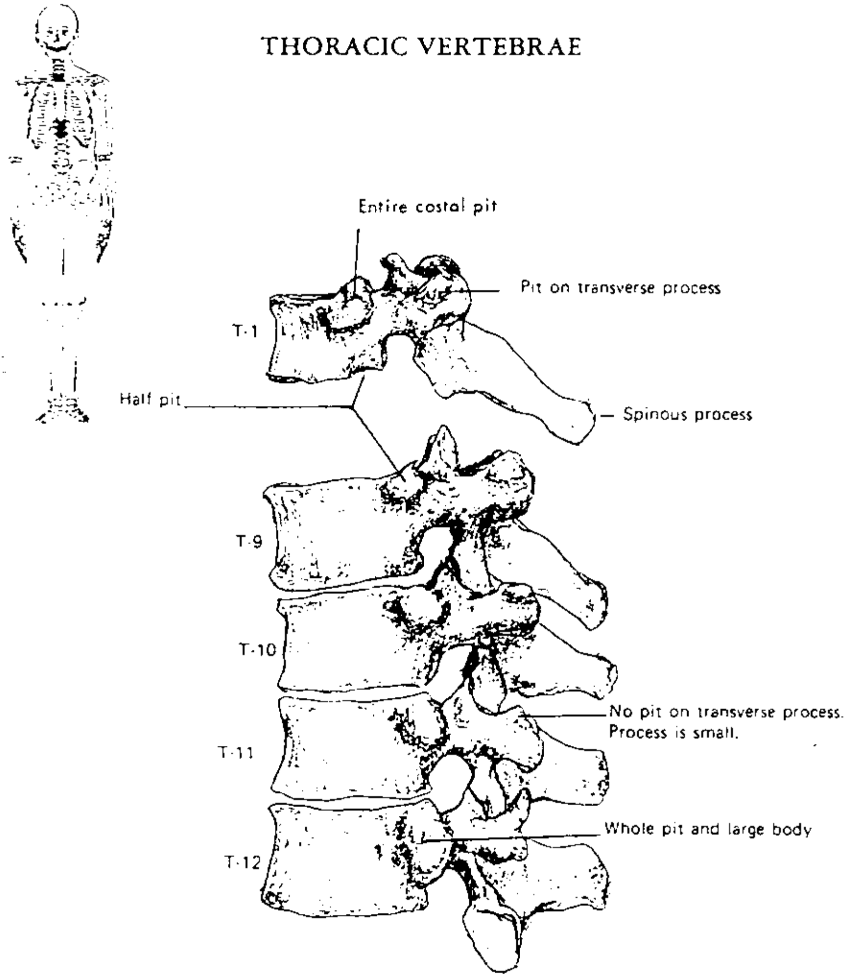


Figure 56. Characteristic features of the thoracic vertebrae (left view).

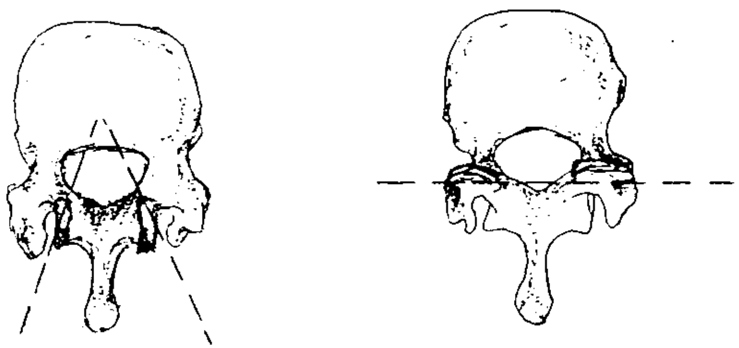
Anatomical Characteristics of Importance in Identification

All have costal pits on the sides of the bodies and on most of the transverse processes for articulation with the ribs. Most thoracic vertebrae have costal pits at the borders; one-half at the superior and one-half at the inferior border so placed that each completes, with the adjacent vertebra, a cavity for the head of a rib.

None of the thoracic vertebrae has transverse foramina.

Bones of Similar Shape where Confusion May Arise

Lumbar vertebrae. Carefully check for articular pits (facets) that occur only on the body of the thoracic vertebrae and for the angle of the articular processes, which form a sharp angle in lumbar vertebrae but are parallel in thoracic vertebrae (Figure 57).



LUMBAR VERTEBRA
(note articular angle)
a

THORACIC VERTEBRA
(parallel articular surfaces superior and inferior)
b

Figure 57. Characteristic differences between lumbar (a) and thoracic (b) vertebrae.

Thoracic Vertebrae of Special Interest

Number 1

This has a whole and a half costal pit.

Numbers 2 through 9

All have half pits on the superior and inferior bodies.

Number 10

This has whole pits on the body and on the transverse process.

Number 11

This has a whole pit on the body but none on the transverse process.

Number 12

This resembles Number 11, except that the inferior articular surfaces are not parallel and assume the lumbar pattern.

Lumbar Vertebrae: 5 Unpaired, Irregular Bones (Figure 58)

The lumbar vertebrae are the largest of the presacral vertebrae and support the weight of the body above the pelvis.

Type	Region	N
Lumbar	lower back	5

Anatomical Characteristics of Importance in Identification

No transverse foramina.

No costal pits for articulation of the ribs.

Largest of the movable vertebrae.

Transverse spines slant upward.

Spinous processes are larger and are more horizontal than in thoracic vertebrae.

The superior and inferior articular facets are U-shaped (Figure 57a) (for greater support) and are different from the parallel-type articulation of the cervical and thoracic vertebrae (Figure 57b).

Bones of Similar Shape where Confusion May Arise

Thoracic vertebrae. Note that there are no articular facets on the body for ribs, and the angles of the articular processes are different from the thoracic vertebrae (Figure 57).

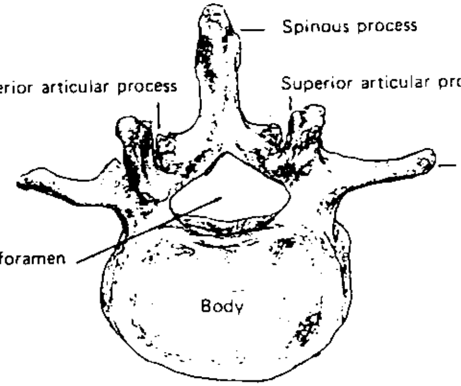
Sacrum: 5 Unpaired, Irregular Bones (Figure 59)
Coccyx: 4 Unpaired, Irregular Bones (Figure 59)

Subadult Bones

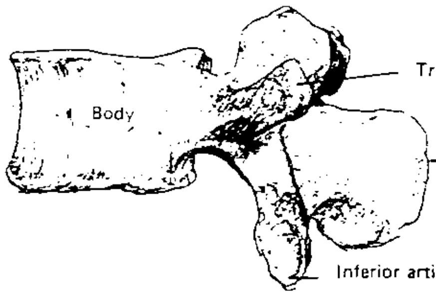
The sacrum ossifies from 35 centers, with each of the 5 sacral segments having the typical vertebra's 3 primary centers plus 2 for the costal elements (Figure 60). Segments 4 and 5 have no costal centers. The costal elements begin to fuse with each other about puberty.

Epiphyseal rings for bodies appear around puberty, with the rings and bodies fusing from below toward the upper end of the 18–25-year range. Late in life the coccyx often fuses with the sacrum.

LUMBAR VERTEBRAE



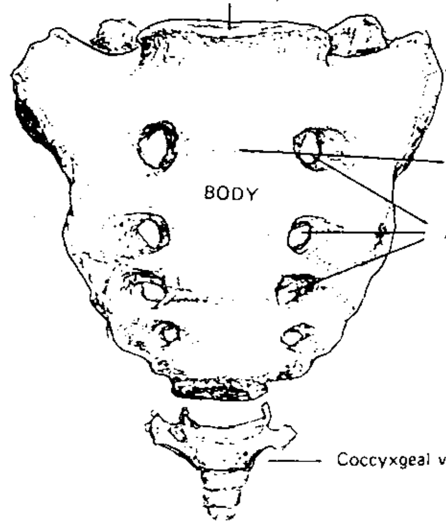
CRANIAL VIEW



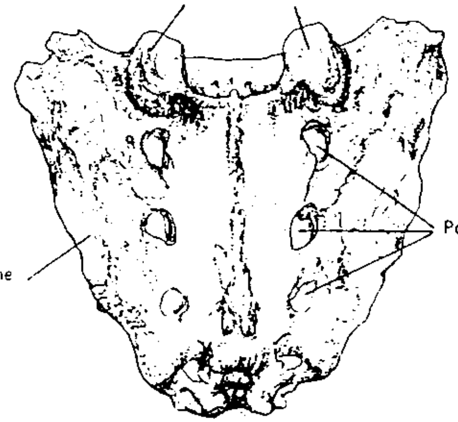
LATERAL VIEW

Figure 58. Characteristic features of the lumbar vertebrae.

SACRUM AND COCCYX



ANTERIOR OR PELVIC VIEW



DORSAL OR BACK VIEW

Figure 59. Characteristic features of the sacrum and coccyx.

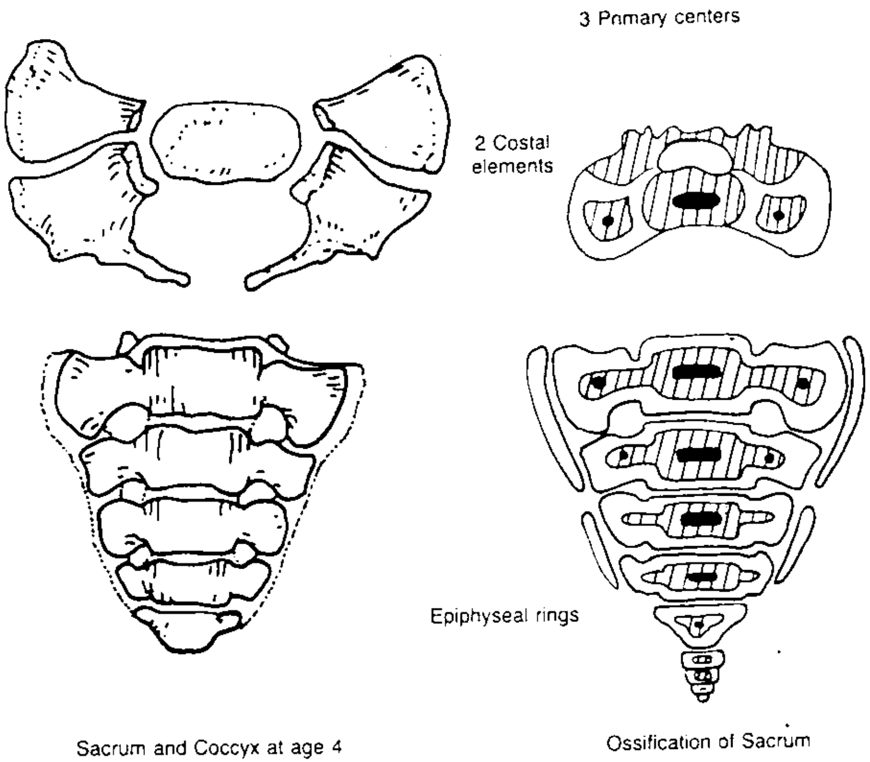


Figure 60. Ossification centers of the sacrum and coccyx.

Discussing final epiphyseal closure, McKern and Stewart (1957:97) state:

> As early as 18 years but any time between 18 and 25 years, the epiphyseal cap begins to unite to the billowed surface of the medial end of the clavicle. Union begins at the approximate center of the face and spreads to the superior margin where it may progress either anteriorly or posteriorly. From 25 to 30, the majority of cases are undergoing terminal union. The last site of union is located, in the form of a fissure, along the inferior border. With the obliteration of these fissures (at age 31), the epiphysis is completely united.

Adult Bones

The sacrum usually is composed of five separate bones that unite into a single triangular-shaped unit in adulthood. It is a large, curved, wedge-

shaped bone that forms the base of the vertebral column and firmly connects with the two hip bones at the sacroiliac joint. The sacrum rapidly decreases in size from the first vertebra (which is the largest) to the fifth (which is rudimentary).

The sides of the upper three vertebrae of the sacrum form a large articular surface that joins with the iliac portion of the hip bones. The ala, or wing, is the large portion of bone between the body of the sacrum and the articular surfaces. The sacrum articulates with the fifth lumbar vertebra superiorly at the promontory, with the iliac portion of the innominate (hip) laterally, and with the coccyx inferiorly.

The anterior and posterior sacral foramina transmit nerves, arteries, and veins.

Type	Region	N
Sacral	pelvis	5
Coccygeal	"tail"	4–5

Bones of Similar Shape where Confusion May Arise

When the sacrum is fragmentary it is possible to confuse it with the lumbar vertebrae, especially the fourth and fifth. Remember that the lumbar vertebrae do not have alae.

Measurements of the Sacrum (Figure 61a)

1. Maximum anterior height (sliding caliper). Measurement taken from the sacral promontory to the middle of the anteroinferior border of the last sacral vertebra (usually the fifth). For comparative purposes use only sacra with five segments (A–B).
2. Maximum anterior breadth (sliding caliper). Measures the greatest distance between the wings (lateral masses) of the first sacral vertebra (C–D).

$$\text{Sacral Index} = \frac{\text{sacral anterior breadth} \times 100}{\text{sacral anterior height}}$$

Racial Indices of the Sacral Index (from Wilder 1920:118)

	Males	Females
Negroes	91.4 (33)	103.6 (18)
Egyptians	94.3 (7)	99.1 (2)
Andamanese	94.8 (22)	103.4 (35)
Australians	100.2 (14)	110.0 (13)
Japanese	101.5 (37)	107.1 (30)
Europeans	102.9 (63)	112.4 (43)

Sex Estimation (Figure 61b)

The sacrum generally is more curved in males and flatter in females.

In some cases the width of the body of the sacrum to the ala is greater in males. Anderson (1962:142) has noted that in females the width of the first sacral body (articular area) is equal in width to each ala.

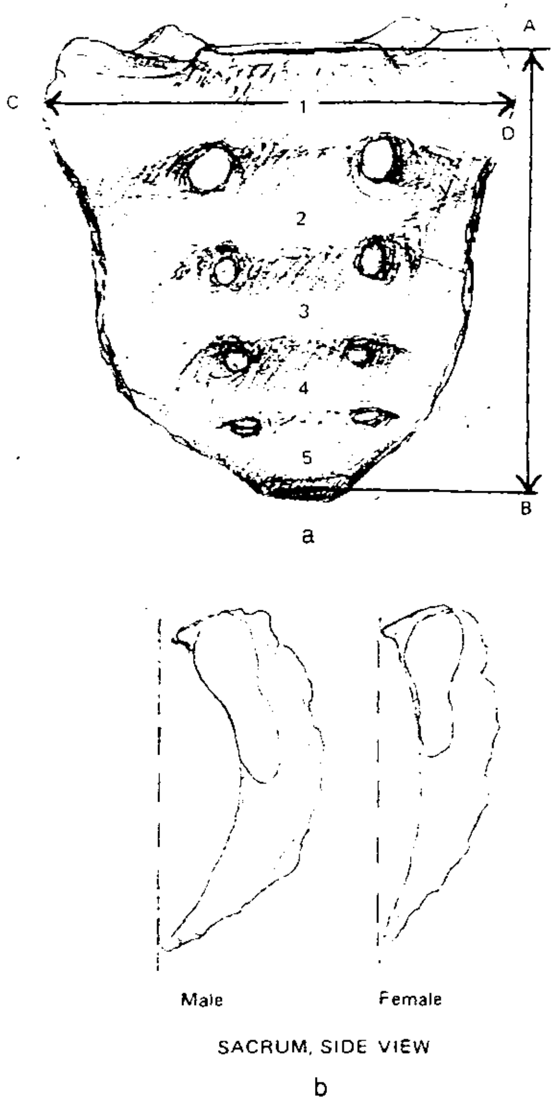


Figure 61. The sacrum: a, landmarks for measurement; b, estimating sex using sacral curvature.

Additional Observations

Record the number of segments in the sacrum, four to six (see numbers on Figure 61a). Note also a sacralized (partly fused) fifth lumbar or a first sacral vertebra that is partly free (lumbarized). In older individuals note arthritic lipping.

Sternum: Unpaired, Flat Bone (Figure 62)

The sternum, or breast bone, is a flat plate of bone situated in the ventral (front) wall of the thorax. It is similar to a broad sword, is slightly concave on the dorsal (back) surface, and has three parts:

Manubrium—handle.
Corpus sterni—body or blade.
Xiphoid process—tip.

In young individuals it is composed of six segments:

1st—remains separate and forms the manubrium.
2nd–5th—fuse to form the body.
6th—remains separate and forms the tip.

Anatomical Characteristics of Importance in Identification

Manubrium—the broadest and thickest part of the bone. The suprasternal or jugular notch easily can be felt in the midline at the superior end of the sternum.

Body—longer, narrower, and thinner than the manubrium. The lines of union of the four pieces making up the body can be seen in the adult bone.

Xiphoid process—thin and the least developed of the parts of the sternum. It is cartilaginous in early life, partly ossified in adults, and in old age tends to become ossified throughout and fused with the body.

Bones of Similar Shape where Confusion May Arise

None.

Additional Observations

Occasionally in the corpus sterni there will be a foramen (Figure 63). Sternal foramina are single, usually oval to circular in shape, and range in diameter from 3 to 18 mm. McCormick (1981:249–52) found the foramina to be present in 7.7% of 324 cadavers. He states that "such foramina were never found in individuals younger than 20 years of age, but occurred at all later ages to the extremes of life (oldest—88 years) and were about twice as common in men as in women, occurring in 9.6% and 4.3% respectively."

STERNUM

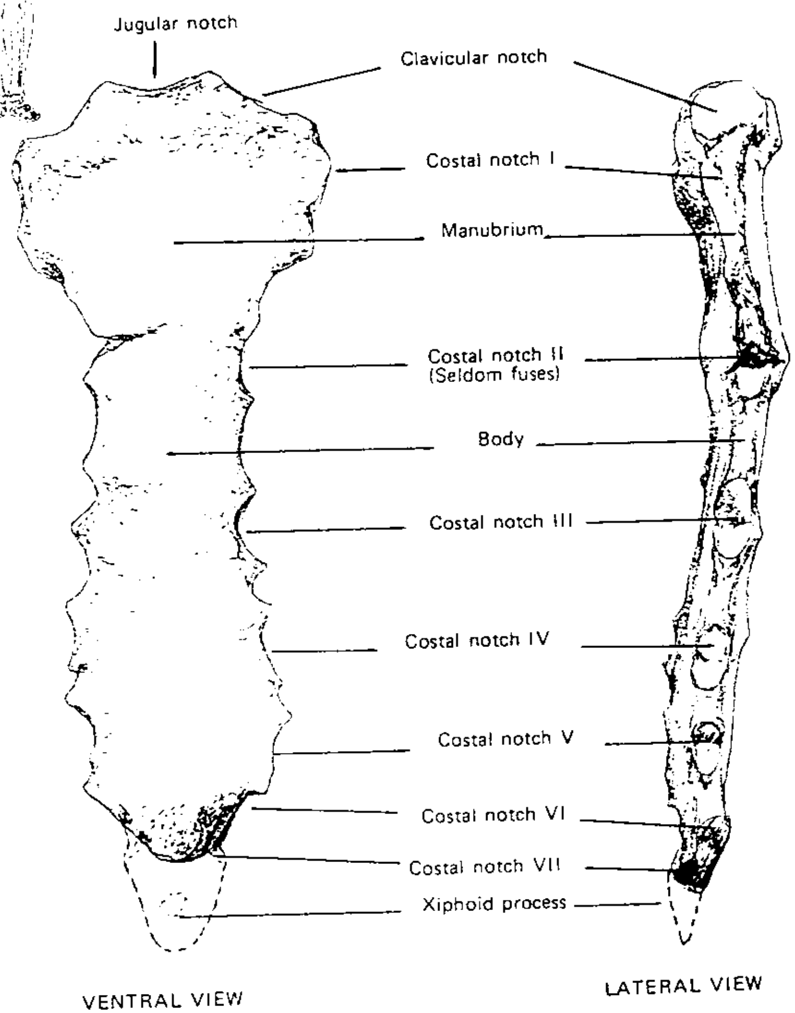


Figure 62. Characteristic features of the sternum.

Figure 63. Sternal foramen.

Ashley (1956:88) states that "it is apparent that the presence or absence of a sternal foramen is determined in the pre-ossification stage of development, i.e., when the sternum is still cartilaginous."

Care should be taken in forensic cases not to confuse a sternal foramen with a gunshot wound. The foramina always are single and are located on the midline in the lower third of the body of the sternum. The edges of the foramen are smooth (McCormick 1981:249). A gunshot wound would produce beveling on either the dorsal or ventral surface as well as possible fracture lines.

Sex Estimation

In many cases the body of the sternum in males is more than twice the length of the manubrium. In females the body is less than twice the length of the manubrium.

Jit *et al.* (1980) have developed a formula that uses three sternal measurements to determine sex: length of the manubrium, length of the mesosternum, and width of the sternebra (Figure 64).

Based on measurements taken on 400 North American Indian sterna (312 males, 88 females), Jit *et al.* (1980:217) concluded that "if the combined length of the manubrium and mesosternum was more than 140 mm the sternum was male, and if less than 131 mm it was female."

Stewart and McCormick (1983) measured the sternal length on chest-plate X-rays of 617 autopsied adult Americans to assess the ability to predict sex. Manubrial and mesosternal lengths were measured individually and the sum of their lengths obtained in each case. They noted that: "The combined manubrio–mesosternal lengths were more easily documentable when significant xyphoidal fusion was not present" (Stewart and McCormick 1983:217).

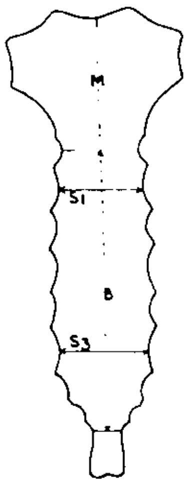


Figure 64. An outline of the sternum indicating measurements taken to estimate sex. M = length of the manubrium, B = length of the mesosternum, S_1 = width of the first sternebra, and S_3 = width of the third sternebra (from Jit *et al.* 1980:218).

In their sample no male measurement fell below 121 mm, and no females were above 173 mm. The range of 143–57 mm is the main area of overlap between females and males and gave predictive values that may be less than 80% accurate. Their measurements for the length of the sternum in men and women are given in Table 16.

Stewart and McCormick (1983:220) note that the range in sternal length is greater in cadavers from the United States than among those reported from northern India, and they suspect that their data are more representative of the United States population with its large multiracial mixture.

TABLE 16.

Length of the Sternum in Adult Males and Females.[a]

Length[b]	Males			Females		
	Xphoid unfused	Xphoid fused	Total	Xphoid unfused	Xphoid fused	Total
0–120	0	0	0	11	1	12
121–132	4	1	5	38	16	54
133–137	2	1	3	31	16	47
138–142	4	2	6	33	14	47
143–157	76	43	119	46	39	85
158–162	32	25	57	4	2	6
163–166	36	24	60	1	0	1
167–173	29	32	61	2	2	4
174–194	19	31	50	0	0	0
Total	202	159	361	166	90	256

[a]After Stewart and McCormick (1983:Table 1).
[b]Measurements given in mm.

Scapula: Paired, Flat Bones (Figure 65)

Subadult Bones

Ossification of the scapula occurs from two primary centers (the body of the scapula and the coracoid) and seven secondary centers (Figure 66).

The coracoid fuses with the scapula beginning about the fifteenth year along a line that includes the upper part of the glenoid cavity, and usually is completed by the eighteenth year.

The scapula usually presents six epiphyses:

Location of epiphyses	Age of union
2 for the coracoid process	15–18 years
1 for the glenoid cavity	15–18
1 for the acromion	16–22
1 for the inferior angle	17–22
1 for the medial (vertebral) border	17–23

There appears to be great variability in the age of union of the epiphyses of the scapula (see section on age estimation below).

SCAPULA

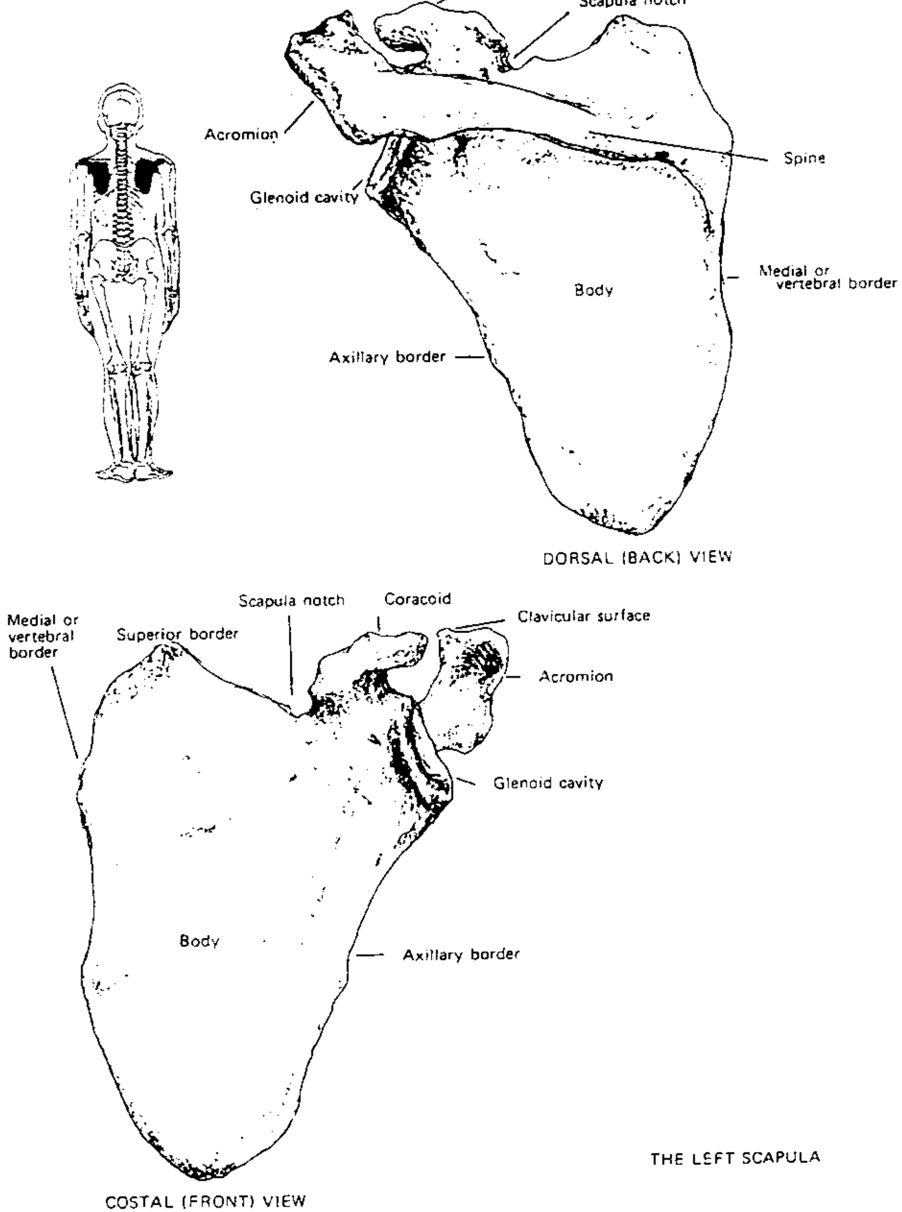


Figure 65. Characteristic features of the scapula (left bone depicted).

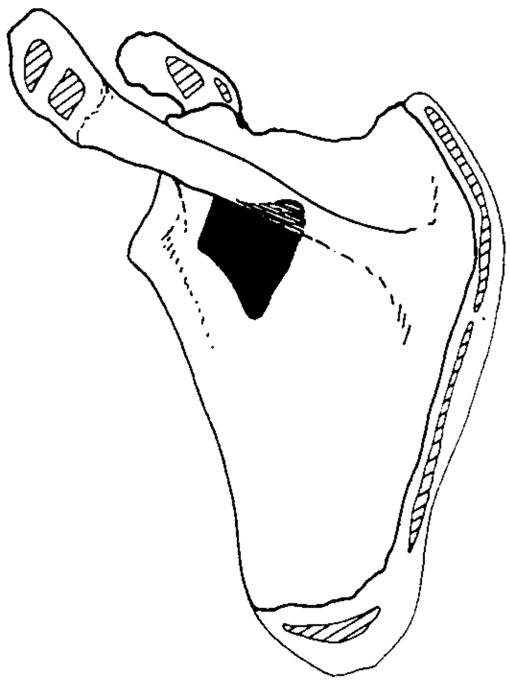


Figure 66. Ossification centers of the scapula.

Adult Bones

The scapula is a large, flat bone that is triangular in shape. It is situated on the dorsal (back) side of the thorax between the level of the second and seventh ribs. From the bone there are two projecting processes: (1) the coracoid process (for muscle attachments); and (2) the spine, which terminates laterally in the acromion (articulates with the clavicle). The function of the scapula is to provide attachments for muscles and to form the socket of the shoulder joint where it articulates with the humerus.

The greater part of the scapula consists of a thin triangular plate of bone known as the body, from which the coracoid extends anteriorly and the spine posteriorly.

The medial or vertebral border is the longest of the three borders and can present a convex, straight, or concave pattern (particularly in the middle one-third section). The axillary border is the thickest and extends from the lower margin of the glenoid cavity to the inferior angle of the bone. The superior border is the shortest of the three borders and

terminates laterally at the scapular notch. The scapular notch shows great variability—it may almost be absent, may present a notch that is either shallow, medium, or deep, or may be a complete foramen.

Anatomical Characteristics of Importance in Identification

Body—concave when viewed from the anterior or front side (anterior side often referred to as the costal surface).

Coracoid process—anterior projection.

Spine—ending in the acromion or posterior projection.

Glenoid cavity—articulator for the head of the humerus.

Bones of Similar Shape where Confusion May Arise

Hip bones (innominates). Both are flat bones, but the rest of the anatomy is not similar. The body of the scapula is thinner than the hip bones and usually presents thinner and sharper borders. On some cases the fragmentary scapula may be confused with the flat bones of the cranium. It should be remembered that cranial bones have an inner and outer table of hard, compact bone and a diploë of loose tissue between those. Diploë is not found in most of the scapula, and no suture line occurs in the scapula.

Side Identification

Hold spine toward you, concave side away; both the coracoid and the acromial processes, which should be superior (on top), point to the side the bone is from.

With spine toward you and the coracoid superior, the vertebral border always is toward the midline (along the thoracic vertebrae) and therefore is opposite the side the scapula comes from. For example, when held in this position, if the vetebral border is on the right side of the bone, the bone is from the left side of the body and vice versa.

The scapula in man, and to a lesser extent in some of the primates, is expanded anterioposteriorly far in excess of that of most other mammals. The infraspinous process is the main part that has lengthened in man.

Measurements of the Scapula (Figure 67)

1. Maximum length (total height) (sliding caliper or osteometric board). The maximum straight-line distance (A–B) from the superior to the inferior border.

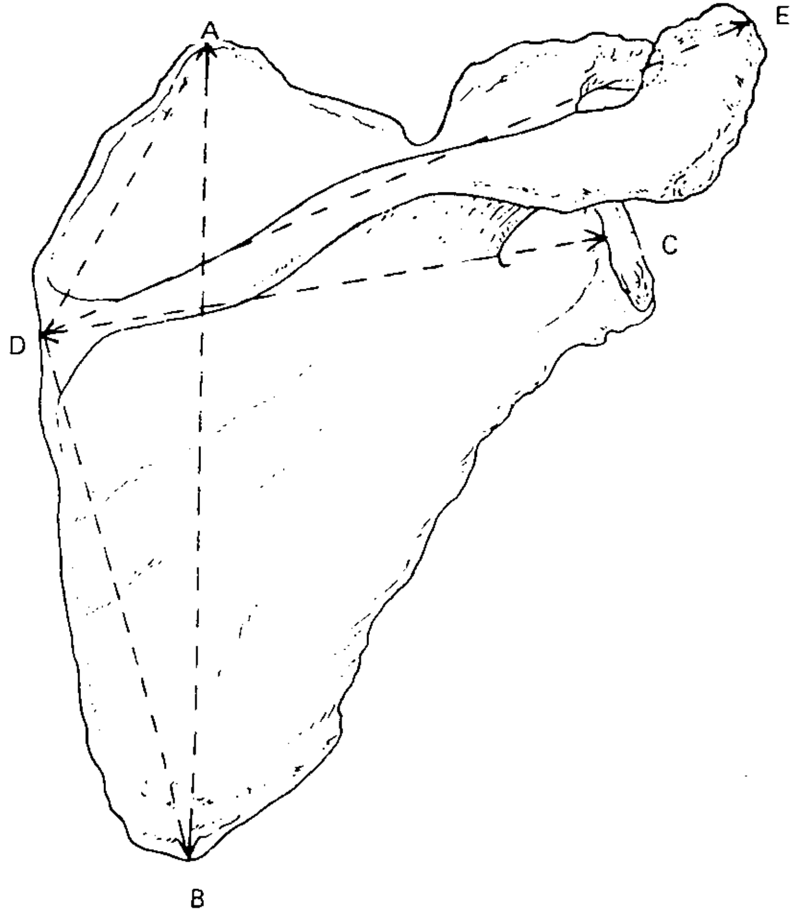


Figure 67. Landmarks for scapula measurement.

2. Maximum breadth (sliding caliper). From the middle of the dorsal border of the glenoid fossa to the end of the spinal axis on the vertebral border (C–D).
3. Length of spine (sliding caliper). From the end of the spinal axis on the vertebral border (same point as above) to the most distal point on the acromion process (D–E).
4. Length of supraspinous line (sliding caliper). From the end of the spinal axis on the vertebral border (same point as above) to the top of the anterior angle (A–D).

5. Length of infraspinous line (sliding caliper). From the end of the spinal axis on the vertebral border to the tip of the posterior angle (D–B).

$$\text{Scapular Index} = \frac{\text{maximum breadth} \times 100}{\text{maximum length}}$$

Additional Observations

The form of the vertebral border may be convex, straight, concave, or any combination of these (Figure 68).

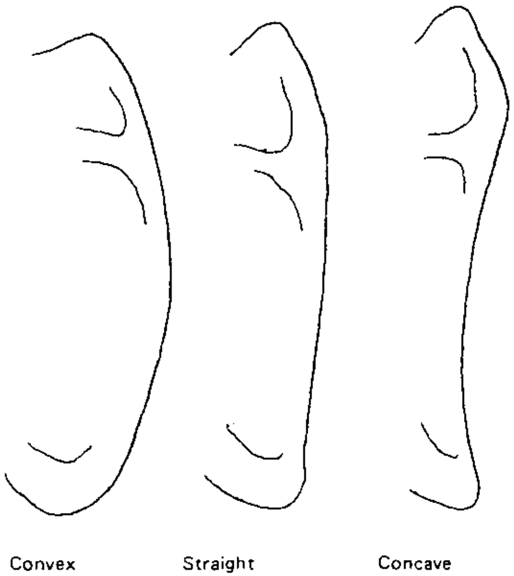


Figure 68. Variation in scapular vertebral borders.

The greatest dimension of the scapula of most mammals (horse, cat, etc.) is in the same direction as the spine; the breadth is at right angles to this (Figure 69).

The shape of the notch formed by the superior border of the scapula and the coracoid process may be absent, shallow, medium, deep, or may be a foramen (Figure 70).

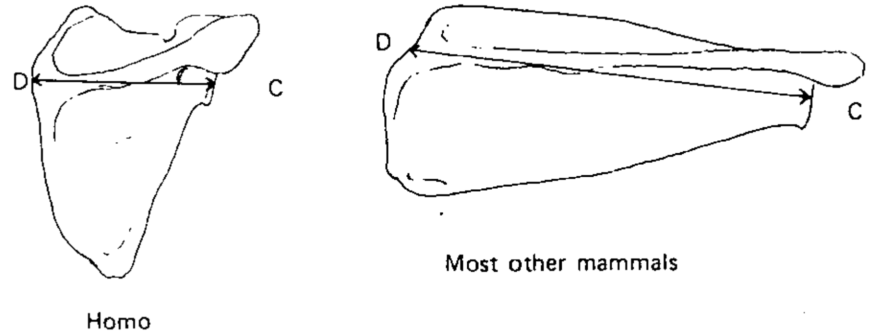


Figure 69. Variations in the scapulae of *Homo sapiens* and most other mammals (stylized).

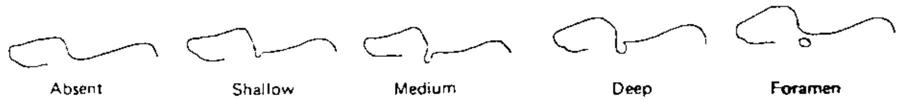


Figure 70. Variations in the morphology of scapular notches.

Age Estimation

Ossification of the scapula and the appearance and union of the epiphyses are given in Figure 66. Table 17 (after Stevenson 1924:54; and other, more recent sources) summarizes the ages assigned to union of the epiphyses.

In the older age range, Graves (1922:27) has noted the appearance of "atrophic spots." Atrophic spots are defined as localized, discrete, or coalescing areas of bone atrophy (Graves 1922:27). It should be noted, however, that not *all* translucent areas in the body of the scapula are atrophic spots, no matter what their degree of translucency. There also must be a localized alteration in the vascularity and structure of the bone in addition to translucency.

Atrophic spots vary in size from 3 mm to 10 mm or more, are discrete, and exhibit irregular patterns in their early stages. Later they become ovoid or circular and coalesce to involve the greater portion of the body in some senile bones. In such bones the body becomes very thin, and oval defects varying in size from 2 to 5 mm may occur in the extremely thin portions. One must differentiate between true defects and "pseudo-defects" (which often are found in scapulae following body fracture). True and pseudo-defects "are differentiated from atrophic spots by their larger size, thicker

TABLE 17.

Ages Assigned by Various Authorities for Union of Epiphyses[a]

Authority	Coracoid	Acromion	Inferior angle	Vertical border
Bryce 1915	puberty	22–25	25	25
Dixon 1912	17	22–25	22–24	22–24
Dwight 1911	14–15	18–19	20	20
Geganbaur 1892	16–18	—	—	—
Henle 1871	14–15	16–17	20	21–22
Krause 1909	16–18	19–21	21–22	21–22
Lewis 1918	15	—	25	25
Poirier 1911	20–25	20–25	—	25–28
Terry 1921	15	20	25	25
Testut 1921	14–16	17–18	22–25	20–24
Thompson 1921	15–17	25	20–25	20–25
Flecker 1942	—	17	—	—
Graves 1922	—	—	—	22
Hrdlička 1942	—	—	20	20
Johnston 1961	—	18–19.5	—	—
McKern and Stewart 1957	pre-17	pre-17–23	pre 17–23	pre 17–23
Stevensen 1924	15	19	19–22	19–22
Terry and Trotter 1953	18–25	20	25	25

[a]References dating to 1924 or earlier are from Stevensen (1924:Table 16).

margins and by the absence of alterations in vascularity and bone structure" (Graves 1922:29).

Graves also found that atrophic spots either were absent, small, or infrequent in scapulae from individuals under 45 years of age, whereas the scapulae from individuals over 45 years of age usually showed them in greater number, size, and degree.

Sex Estimation

Krogman (1962:205–6) has summarized the data on sex estimation based on the scapula, and his two tables are reproduced here (tables 18, 19).

Dwight (1894b) states that two dimensions of the scapula are useful as indicators of sex: the maximum length between the superior and inferior angles (Figure 67) and the length of the glenoid cavity (Figure 71, Table 20). Stewart (1979) checked Dwight's measurements using 50 males and 40 females from the Terry Collection and found the latter measurement was

TABLE 18.

Sample of Scapular Dimensions and Indices Arranged by Scapular Index[a]

	Male				Female			
Group	Number	Height total[b]	Breadth	Scapular index	Number	Height total	Breadth	Scapular index
Fuegian	35	16.02	9.90	61.8	28	14.33	9.22	64.3
Eskimo	4	15.70	9.72	61.9	4	(15.87)	(9.85)	62.0
Finn	72	16.55	10.25	62.4	14	14.80	9.32	63.9
New Caledonia	10	14.83	9.60	63.6	5	12.86	8.94	69.5
Europ. white	146	16.76	10.65	63.7	102	13.55	9.05	66.8
Old Peruv. Indian	55	15.83	10.17	64.2	39	13.78	9.17	66.5
Fuegian	7	15.38	9.88	64.3	2	14.20	9.40	66.1
N. W. Indian	10	16.52	10.48	64.3	14	14.07	9.37	66.1
Portuguese	37	15.92	10.21	64.4	20	13.62	9.04	66.5
Fuegian	4			64.8	6			65.7
French	78	15.92	10.37	65.2	68	14.11	9.28	65.9
U.S. white	70	16.40	10.70	65.3	44	14.40	9.60	66.7
Mex. Indian	9	15.80	10.40	65.5	12	13.75	9.75	70.7
Egyptian	6			65.9	9			68.0
Egyptian	11	15.78	10.42	66.5	6	13.0	9.31	68.6
Afr. black	58	15.23	11.19	66.6	15	13.46	9.01	68.2
Amer. Negro	46	16.25	10.90	66.8	18	14.20	9.25	65.0
So. Mongol	20			66.9	4			(65.1)
So. Utah Indian	18	15.10	10.15	67.4	10	13.70	9.70	70.6
Pecos Indian	79	14.74	10.11	68.3	24	13.42	9.67	73.5
Melanesian	20			68.6	11			69.1
Melanesian	10	14.90	10.29	69.1	12	13.42	9.20	68.6
Lenape Indian	4	15.20	10.60	69.5	9	13.90	9.90	70.7
Pima and Pueblo	5	15.50	11.08	71.0	5	13.80	9.95	72.0
Negrillo	4	13.15	10.03	77.1	6	12.10	8.93	73.8

[a]From Hrdlička (1942:381).
[b]Measurements are in cm.

TABLE 19.

Scapular Dimensions and Indices: Ranges of Variation[a]

	Sample total	Height total	Height, infraspinous	Breadth (Broca's)	Indexes scapular total	Infra-spinous
Male						
All whites	1200	13.7–19.0[b]	9.8–14.7	8.6–12.4	53.8–85.4	68.1–111.1
		16.04[c]	12.08	10.49	65.0	86.9
		32.8[d]	40.6	36.2	48.6	49.5
North American Indian	229	13.0–18.4	9.9–14.8	8.9–12.0	57.3–75.9	66.2–101.3
		15.36	11.69	10.115	65.86	86.52
		32.2	41.9	30.6	28.2	40.6
Alaskan Eskimo	239	13.1–18.4	10.0–15.0	8.7–12.2	54.2–72.5	67.4–94.6
		16.22	12.77	10.12	62.4	79.2
		32.7	39.2	34.6	27.7	34.3
American Negro	126	14.1–18.7	9.9–14.3	9.0–12.4	58.9–76.9	76.8–111.1
		15.98	11.66	10.66	66.7	91.4
		28.8	36.9	31.9	27.0	37.5
Female						
All whites	457	11.7–16.8	8.5–13.0	8.1–11.3	55.6–84.7	71.4–116.7
		14.19	10.67	9.39	66.3	88.1
		35.9	42.2	34.1	43.9	51.4
North American Indian	179	11.4–16.4	8.4–13.0	8.3–10.9	58.4–86.8	72.3–114.3
		13.73	10.535	9.615	70.0	91.245
		36.4	43.7	27.0	40.6	46.0
Alaskan Eskimo	197	12.3–17.1	9.2–14.2	8.0–10.3	56.7–76.6	65.0–98.0
		14.10	11.06	9.25	65.6	83.6
		34.0	45.2	24.9	30.3	39.5
American Negro	46	12.6–16.1	8.8–12.4	8.7–10.6	57.7–76.3	75.6–112.8
		14.17	10.23	9.51	67.2	93.0
		24.7	35.2	20.0	27.7	40.0

[a]From Hrdlička (1942:399).
[b]Range.
[c]Mean.
[d]Range/Average Index or R.A.

TABLE 20.

Length of Glenoid Cavity of Scapula

Length[a]	Females	Sex?	Males
Scapula length	<129	140–159	>160
Glenoid cavity length	< 34	34–36	> 37

[a]Measurements given in mm.

not well defined. Stewart (1979:98) translates Vallois' (1932) directions for glenoid-cavity length as follows:

> The inferior point is easy to find, for, at this level the articular margin generally is sharp. But the superior point is different, for there, the border of the cavity forms the blunt projection of the supra-glenoid tubercle; I have utilized therefore the most elevated point of this projection, easy to locate when one examines the cavity in profile.

To take this measurement use a sliding caliper and place the stable end on the sharp inferior border (A) and the moveable end on the elevated point of the inferior projection (B) (Figure 71).

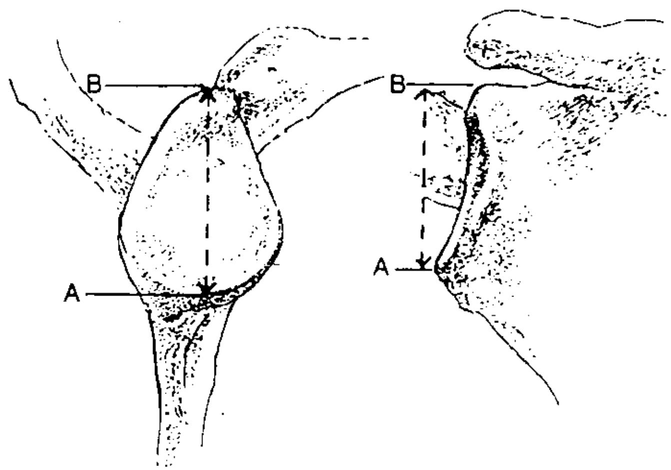
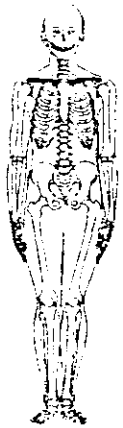


Figure 71. Landmarks for measuring scapular–glenoid-cavity length for sex estimation.

Clavicle: Paired Long Bones (figures 72, 73)

Subadult Bone

The clavicle is the first of the bones of the body to ossify, usually beginning about the fifth week after birth (Figure 74). A secondary center (epiphysis) appears at the sternal end between 12 and 21 years of age and is the last of the epiphyses of the body to unite (in most individuals by age 25).



CLAVICLE

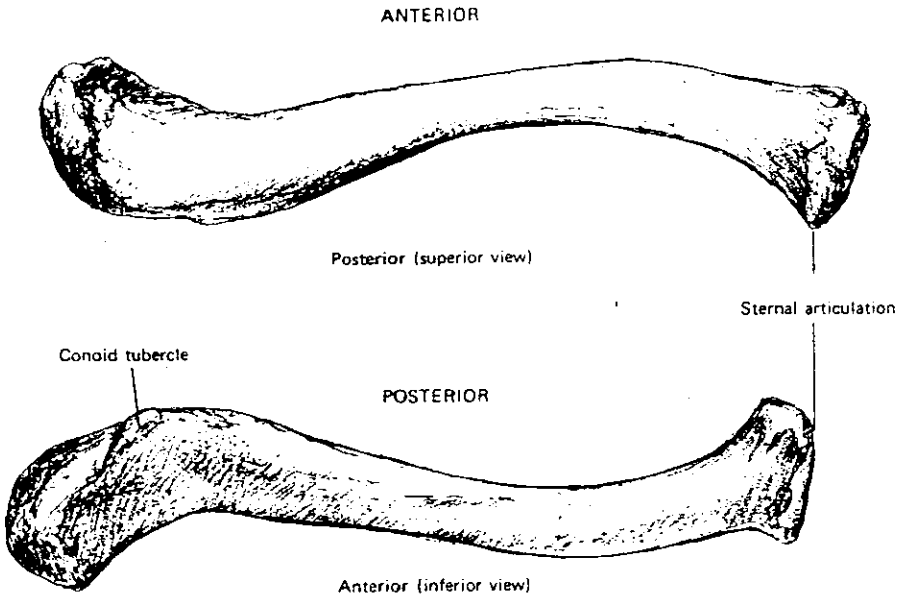


Figure 72. Characteristic features of the clavicle (left bone depicted).

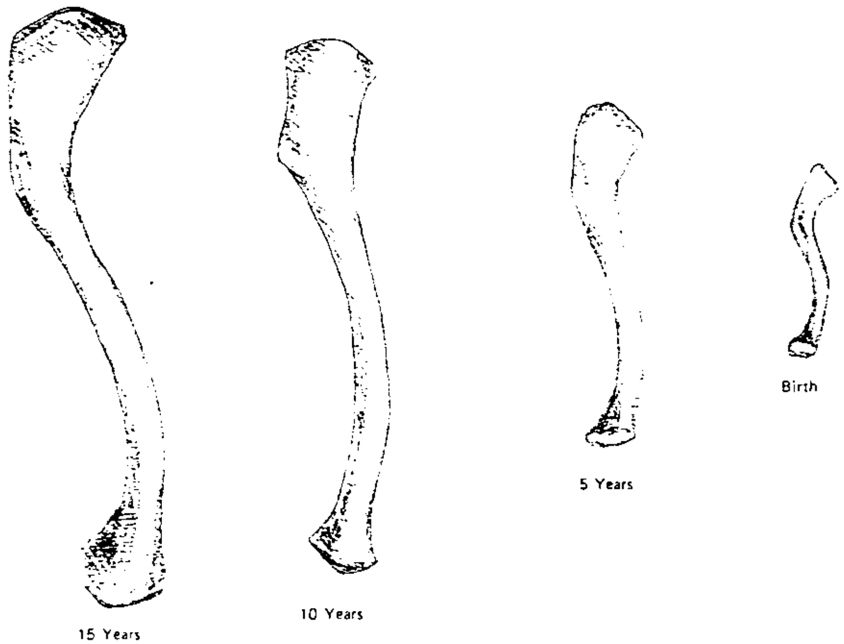


Figure 73. Developmental stages of the clavicle at birth, and at 5, 10, and 15 years.

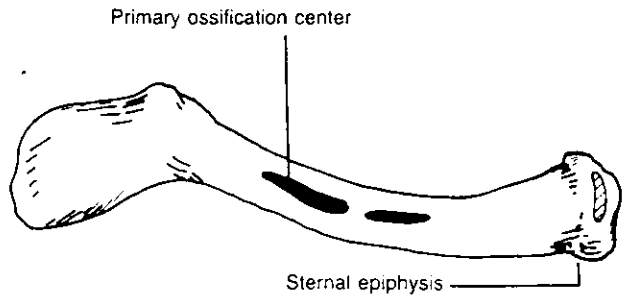


Figure 74. Ossification centers of the clavicle.

Adult Bone

The clavicle, or collar bone, is a long bone with a shaft and two ends. It is situated immediately above the first rib and extends laterally from the

upper border of the manubrium (sternum) and backwards to the acromion of the scapula. It functions as a strut or prop to the shoulder, thereby holding the scapula and upper limb laterally, backward, and slightly upward.

Animals that use their forelimbs merely for support or locomotion (e.g., horses, cows, dogs, bison) either have no clavicles or only rudimentary ones. Animals that use their forelimbs for flying, climbing, grasping, or burrowing (e.g., primates, rodents, bats) have clavicles.

The loss of the clavicle results in "lengthening" of the limb in a functional sense, i.e., instead of swinging from the glenoid the forelimb swings from the muscular attachment between the scapula and thorax. Such modification results in a longer stride (ground distance-degree of movement).

Bones of Similar Shape where Confusion May Arise

The end of the clavicle can be confused with the acromial process of the scapula. The acromial process of the scapula has no conoid tubercle.

Side Identification

The shoulder, or distal, end is flattened.

The sternal, or medial, end is rounded.

The conoid tubercle is on the inferior (down) surface near the shoulder end and always is posterior. The conoid tubercle always is inferior (down) and in the back when in anatomical position.

Figure 75a illustrates the inferior view of the left and right clavicles with the conoid tubercle facing the viewer.

Measurements of the Clavicle

1. Maximum length (osteometric board or sliding caliper). One end of the bone is placed against the stationary end of the board, and the movable end of the board is brought into contact with the opposite end of the clavicle. The clavicle is moved from side to side and up and down until the maximum length is obtained (A–B) (Figure 75b).
2. Circumference at middle of bone (metal tape or strip of graph paper). This measurement is taken at the middle of the shaft.
3. Claviculohumeral Index: useful as an indicator of the relative development of the thorax.

$$\text{Claviculohumeral Index} = \frac{\text{maximum length of clavicle} \times 100}{\text{maximum length of humerus (from same side as clavicle)}}$$

4. Robustness Index: useful as an indicator of sex.

$$\text{Robustness (circumference:length) Index} = \frac{\text{midclavicular circumference} \times 100}{\text{maximum length of clavicle}}$$

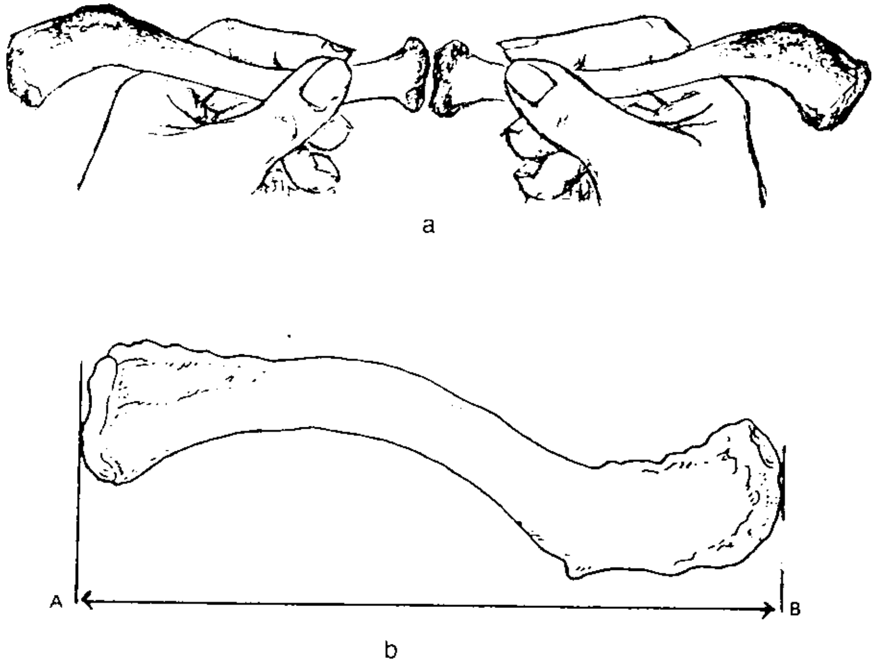


Figure 75. The clavicle: a, standard anatomical position for identification of side; b, landmarks for measurement.

Age Estimation

According to McKern and Stewart (1957), the medial clavicular epiphysis begins to unite in the seventeenth or eighteenth year. They found unattached epiphyses as late as the twenty-second year, but no cases of complete union were found before age 23. In summary, they state:

> As early as 18 years but any time between 18 and 25 years, the epiphyseal cap begins to unite to the billowed surface of the medial end of the clavicle.

Union begins at the approximate center of the face and spreads to the superior margin where it may progress either anteriorly or posteriorly. From ages 25 to 30, the majority of cases are undergoing terminal union. The last site of union is located, in the form of a fissure, along the inferior border. With the obliteration of these fissures (at age 31), the epiphysis is completely united (McKern and Stewart (1957:91–92).

Recent research by Sorg *et al.* (1985) on timing of the epiphyseal union of the medial clavicle in white females has found much greater variation in the time of union than previously thought. They found fusion as early as a.. 15 and unfused medial epiphyses as late as age 32 in a sample ..sisting of the chest X-rays of 131 females.

Suchey and some of her students and colleagues have analyzed epiphyseal union of the medial clavicle in a large sample (605 males and 254 females) of modern Americans, ages 11 to 40 (Owings 1981; Suchey *et al.* 1984; Webb and Suchey 1985). Their sample includes American whites, American blacks, Latin Americans, and Orientals. This is the first skeletal investigation using a large sample of individuals of known age since the 1957 McKern and Stewart study, and in addition includes females in the data base, which was not done by McKern and Stewart. The data supplied by Suchey (tables 21, 22) vary slightly from those reported by Suchey *et al.* (1984) and include information on both the right and left clavicles.

Owings (1981) and Webb and Suchey (1985) suggest the following general rules for skeletal-age determination using epiphyseal union of the medial clavicle (Table 23).

Sex Estimation

The accuracy of estimating an individual's sex based on measurements of the clavicle has met with varying degrees of success.

Thieme (1957) uses clavicle length as one of a series of eight measurements to estimate sex in the Negro skeleton. Although this single measurement is not too accurate for estimating sex, Thieme reports the following data for an American Negro sample (Table 24).

Jit and Singh (1966) used data on adult clavicles from India to predict sex, and they report the following:

> [T]here is no such single character which can determine the sex of all clavicles. Depending on the length alone, the sex can be decided in 8 per cent of male and 14 percent of female right clavicles and in 20 per cent of male and 12 percent of female bones if the left clavicle is considered. Thus, about 80 to 92 per cent of male clavicles cannot be distinguished by this character. The weight of the clavicle, which can distinguish 24 per cent male bones if the right clavicle is available and 35 per cent if the left is available, is a better guide than the length for the male cases. However, for finding the female clavicles, weight does not help in more than 2 per cent in case of right clavicles and its value is zero per cent for evaluating sex from the left

TABLE 21.

Age Distribution of the Stages of Union for Epiphyses of the Medial Clavicle in Males[a]

		Right						Left			
Age	N	Stage of union[b]				Age	N	Stage of union			
		1	2	3	4			1	2	3	4
11	2	100[c]	-	-	-	11	2	100	-	-	-
13	3	100	-	-	-	13	3	100	-	-	-
14	6	100	-	-	-	14	7	100	-	-	-
15	12	100	-	-	-	15	12	100	-	-	-
16	24	96	4	-	-	16	25	92	8	-	-
17	21	82	9	9	-	17	23	83	-	17	-
18	32	56	16	28	-	18	33	52	18	30	-
19	29	41	18	41	-	19	33	55	21	24	-
20	23	26	17	57	-	20	27	30	15	55	-
21	30	10	7	80	3	21	33	9	3	85	3
22	39	5	-	85	10	22	40	12	10	70	8
23	29	3	-	83	14	23	32	6	-	78	16
24	25	4	-	60	36	24	29	3	-	62	35
25	36	-	-	42	58	25	38	3	-	45	52
26	17	-	-	47	53	26	21	-	-	38	62
27	30	-	-	27	73	27	35	-	-	37	63
28	20	-	-	15	85	28	22	-	-	23	77
29	20	-	-	5	95	29	22	-	-	5	95
30	28	-	-	4	96	30	30	-	-	7	93
31-40	124	-	-	-	100	31-40	130	-	-	-	100
Total	550					Total	597				

[a]Courtesy of J. Suchey.
[b]Stages of union:
1) non-union without epiphysis.
2) non-union with separate epiphysis.
3) partial union.
4) complete union.
[c]Stage-of-union figures given in percentages.

TABLE 22.

Age Distribution of the Stages of Union for Epiphyses of the Medial Clavicle in Females[a]

		Right						Left			
Age	N	Stage of union[b]				Age	N	Stage of union			
		1	2	3	4			1	2	3	4
11	1	100[c]	-	-	-	11	1	100	-	-	-
13	-					13	1	100	-	-	-
14	4	100	-	-	-	14	2	100	-	-	-
15	9	100	-	-	-	15	9	100	-	-	-
16	5	100	-	-	-	16	6	66	17	17	-
17	7	58	14	28	-	17	7	43	14	43	-
18	14	21	29	50	-	18	16	19	31	50	-
19	11	46	18	36	-	19	11	18	18	64	-
20	15	7	13	80	-	20	15	7	-	86	7
21	9	11	-	78	11	21	9	11	11	78	-
22	14	-	-	86	14	22	15	-	-	80	20
23	12	8	-	75	17	23	12	-	-	83	17
24	16	-	-	50	50	24	16	-	-	50	50
25	5	-	-	20	80	25	7	-	-	43	57
26	14	-	-	29	71	26	16	-	-	37	63
27	9	-	-	44	56	27	9	-	-	33	67
28	18	-	-	6	94	28	19	-	-	5	95
29	10	-	-	-	100	29	11	-	-	-	100
30	11	-	-	18	82	30	11	-	-	9	91
31	9	-	-	-	100	31	10	-	-	-	100
32	7	-	-	-	100	32	10	-	-	10	90
33	12	-	-	17	83	33	12	-	-	17	83
34-39	20	-	-	-	100	34-39	22	-	-	-	100
Total	232					Total	247				

[a]Courtesy of J. Suchey.
[b]Stages of union:
1) non-union without epiphysis.
2) non-union with separate epiphysis.
3) partial union.
4) complete union.
[c]Stage-of-union figures given in percentages.

TABLE 23.

General Rules for Skeletal Age Estimation Using Epiphyseal Union of the Medial Clavicle[a]

Stages of Union	Males	Females
Non-union with or without separate epiphysis present	25 years or less	23 years or less
Partial union	17–30 years	16–33 years
Complete union	21 years or more	20 years or more

[a]After Owings (1981:43) and Webb and Suchey (1985).

TABLE 24.

Sex Estimation from Clavicle Length[a]

Measurement	Sex	N	Mean mm	Standard deviation	Standard error of mean	Critical ratio (t)
Clavicle length	M	98	158.24	10.06	1.158	13.90
	F	100	140.28	7.99	0.800	

[a]After Thieme (1957).

clavicles. The circumference at the middle of the clavicle is of greatest significance because it can distinguish 72 per cent male cases if the right bone is available. However, by clavicle it can sort out only 48 per cent cases. On the other hand, its utility in the female clavicles is rather poor, being only 10 and 5 per cent in case of right and left bones, respectively. The robustness index has not been found to be of much use in sexing the clavicles, its value being 4 to 8 per cent in male cases and nil in the females. Thus, for positively declaring the bone to be a definitely female one, the length alone is more useful than any other single character because by this method 12 to 14 per cent female clavicles can be easily sorted out, whereas by other individual characters the value varies from zero to 10 per cent only. However, by working out linear combinations of different characters a large percentage of female clavicles can definitely be found out, i.e., 21 to 35 per cent from the left and right clavicles, respectively (Jit and Singh 1966:20).

Ribs: 12 Paired, Flat Bones (Figure 76)

Subadult Bones

Around the eighth week of intrauterine life the ribs begin to ossify from a center near the angle of each rib. Ossification progresses rapidly and by

RIBS

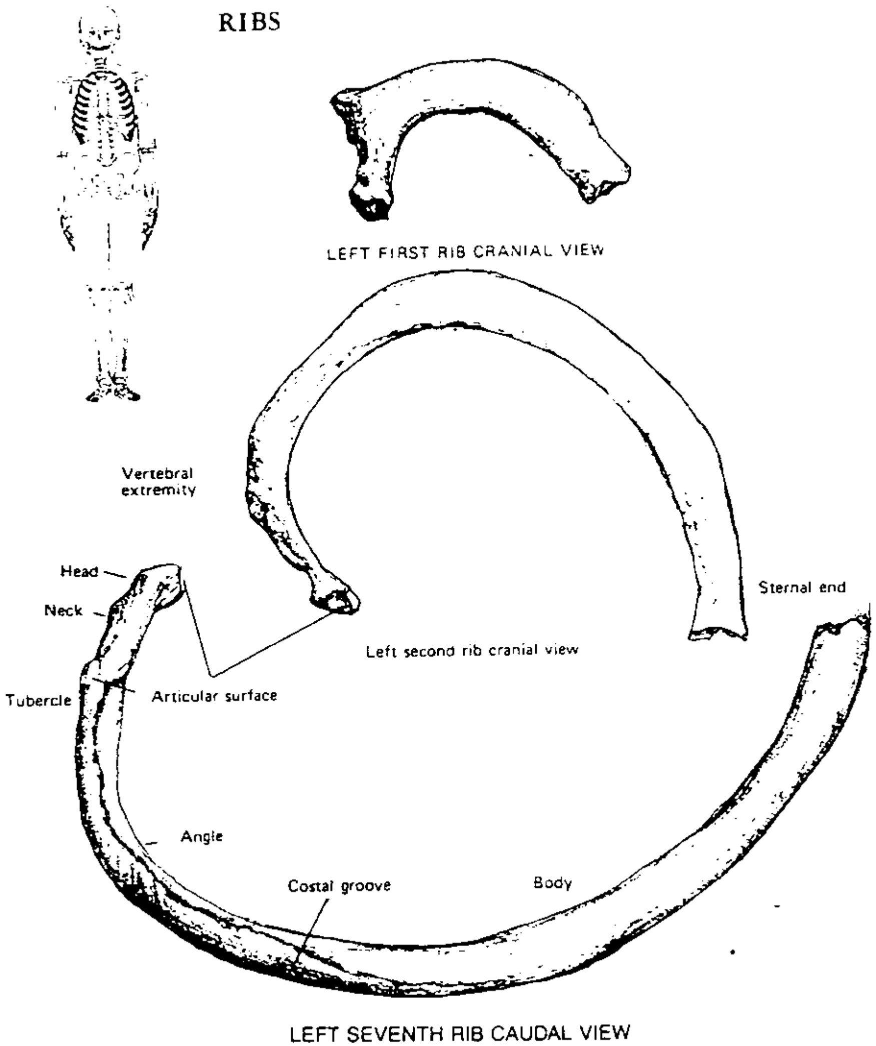


Figure 76. Characteristic features of the ribs.

the end of the fourth month reaches as far as the costal cartilage (Figure 77).

Secondary centers for the head and the articular part of the tubercle appear about puberty and fuse between the ages of 18 and 24. McKern and Stewart (1957:160) state that "ossification begins in the upper and lower

Figure 77. Ossification of a typical rib.

ribs and slowly progresses toward the middle. Thus, the last ribs to become fully united are ribs 4 to 9."

Adult Bones

The ribs—12 on each side—constitute a series of paired, narrow, flattened bones that posteriorly articulate with the vertebral column. The upper 7 pairs directly articulate with the sides of the sternum through cartilage and are termed true ribs. The remaining 5 pairs are classified as false ribs and are of 2 kinds:

1. The eighth, ninth, and tenth ribs have cartilage that ventrally (in the front) connects with the cartilage of the ribs above.
2. The ventral extremities are free and are tipped with cartilage on the eleventh and twelfth ribs.

The ribs are classified as follows:

Rib number	Common Name	Anatomical
First 7 ribs	true	vertebrosternal
8th, 9th and 10th	false	vertebrochondral
11th and 12th	floating	vertebral

Note that the ribs increase in length from the first through the seventh rib and decrease from the eighth through the twelfth. The seventh rib is regarded as the most typical and presents (1) a vertebral extremity that includes a head, a neck, and a tubercle; (2) a shaft, or body; and (3) a sternal extremity.

The cranial (external, or top) surface of a rib is convex and usually fairly smooth. The caudal (internal, or bottom) surface is concave and contains the costal groove on the lower edge. The cranial edge of the rib is blunt, whereas the caudal edge is sharp, with the costal groove on the inside.

The first rib is the broadest, most curved, and usually the shortest of all the ribs. The head usually has only one articular facet. The second rib is longer than the first, strongly curved, but looks more like the ribs below.

Bones of Similar Shape where Confusion May Arise

It is difficult to tell the exact number of the rib without a comparative skeleton.

Side Identification

The head always is dorsal (toward the back), and the tubercle always is caudal (down). This is enough to orient the rib, but additional observations to enforce the above for proper orientation are that the thick edge of the rib should be up (cranial), and the costal groove and the sharp inferior (caudal) edge should be down.

To tell the sides of the first rib, lay the rib on a table; the head will point down (rest on the table) when the rib is oriented as it is in the body. With the head down, the groove for the subclavian vein will be on top.

Age Estimation

The mineralization of the costal cartilage of ribs as an indicator of age has been reported by McCormick (1980), who published a point scale for grading the mineralization of costal cartilage on X-rays of chest plates from 0 (none visible) to 4+ (very severe).

McCormick's research indicates that calcification of the costal cartilage is uncommon below the age of 20 and appears to develop somewhat more slowly in females. He notes that "Mineralization was usually first detectable in the six, seventh, and eighth cartilages adjacent to the sternal borders. At least a 'trace' of mineralization was evident within the costal cartilages in all cadavers over the age of 25 years" (McCormick 1980:737). Moderate mineralization (2+ to 3+) was rare before the age of 40 and unusual after 60. Dense mineralization (3 to 4+) was usual after age 55. McCormick (1980:737) cautions, however, that "mild to moderate (1 to 2½+) mineralization was frequently encountered in cadavers over the age of 50, even to advanced age (80+ years)."

Studies by Iscan *et al.* (1984a, 1984b) and Stewart and McCormick (1984) have focused attention on the age and sex ossification patterns of the sternal end of the ribs. Iscan *et al.* (1984a:1095–96) have established a "phase analysis" based on 118 autopsied white males by direct observation of the sternal end of the right fourth rib, and they state that "The distribution of specimens into phases was based on changes noted in the form, shape, texture, and overall quality of the sternal rib." The model standards for the nine phases defined by Iscan *et al.* (1984a:plates 1–3) are defined and illustrated in figures 78–80.

Figure 78. Model standards of phases 0–2 of sternal-end ossification of the fourth rib in white males (from Iscan *et al.* 1984a:Plate 1; courtesy of M. Y. Iscan and S. R. Loth). Phase 0—The articular surface is flat or billowy with a regular rim and rounded edges. The bone itself is smooth, firm, and very solid (0a–c). Phase 1 (ages 16.5–18.0)—Amorphous indentation is beginning to show in the articular surface, but billowing still may be present. The rim is rounded and regular. In some cases scallops may start to appear at the edges. The bone is still firm and solid (1a–c). Phase 2 (ages 20.8–23.1)—The pit is now deeper and has assumed a V-shaped appearance formed by the anterior and posterior walls. The walls are thick and smooth with a scalloped or slightly wavy rim with rounded edges. The bone is firm and solid (2a–c). Ages based on a 95% confidence interval (from Iscan *et al.* 1984a:Table 2).

Figure 79. Model standards of phases 3–5 of sternal-end ossification of the fourth rib in white males (from Iscan *et al.* 1984a:Plate 2; courtesy of M. Y. Iscan and S. R. Loth). Phase 3 (ages 24.1–27.7)—The deepening pit has taken on a narrow-to-moderate U-shape. Walls still are fairly thick with rounded edges. Some scalloping still may be present, but the rim is becoming more irregular. The bone still is quite firm and solid (3a–c). Phase 4 (ages 25.7–30.6)—Pit depth is increasing, but the shape still is a narrow to moderately wide U. The walls are thinner, but the edges remain rounded. The rim is more irregular, with no uniform scalloped pattern remaining. There is some decrease in the weight and firmness of the bone. The overall quality of the bone, however, still is good (4a–c). Phase 5 (ages 34.4–42.3)—There is little change in pit depth, but the shape in this phase is predominately a moderately wide U. Walls show further thinning and the edges are becoming sharp. Irregularity is increasing in the rim. The scalloped pattern is gone completely and has been replaced with irregular bony projections. The condition of the bone is fairly good. There are, however, some signs of deterioration, with evidence of porosity and loss of density (5a–c). Ages based on a 95% confidence interval (from Iscan *et al.* 1984a:Table 2).

Figure 80. Model standards of phases 6–8 of sternal-end ossification of the fourth rib in white males (from Iscan *et al.* 1984a:Plate 3; courtesy of M. Y. Iscan and S. R. Loth). Phase 6 (ages 44.3–55.7)—The pit is noticeably deep with a wide U-shape. The walls are thin with sharp edges. The rim is irregular and exhibits some rather long bony projections that frequently are more pronounced at the superior and inferior borders. The bone is noticeably lighter in weight, thinner, and more porous, especially inside the pit (6a–c). Phase 7 (ages 54.3–64.1)—The pit is deep, with a wide to very wide U-shape. The walls are thin and fragile with sharp, irregular edges and bony projections. The bone is light in weight and brittle, with significant deterioration in quality and obvious porosity (7a–c). Phase 8 (ages 65.0–78.0)—In this final phase the pit is very deep and widely U-shaped. In some cases the floor of the pit is absent or filled with bony projections. The walls are extremely thin, fragile, and brittle, with sharp, highly irregular edges and bony projections. The bone is very lightweight, thin, brittle, friable, and porous. "Window" formation sometimes is seen in the walls (8a–c). Ages based on a 95% confidence interval (from Iscan *et al.* 1984a:Table 2).

Iscan *et al.* (1985) also have reported on age estimation from the rib by phase analysis for white females. Information on the nine phases as well as the illustrations shown in figures 81–83 have been provided by S. Loth.

Sex Estimation

McCormick and Stewart (1983) examined the chest X-rays of 407 autopsied males and 244 females 20 years of age or older and found a sex difference in the ossification pattern of most individuals. Their data suggest that typical male patterns exhibit peripheral subperichondrial (i.e., marginal) linear ossification (Figure 84). Typical female patterns exhibit a central foci of subperichondrial bands of ossification. These are composed either of multiple, relatively large, often coalescing ossific nodules (Figure 85) or fine, irregular-patterned ossification often arising submarginally as ossific tongues from the costochondral junctions (McCormick and Stewart 1983).

In a later report Stewart and McCormick (1984) discuss two patterns of costal-cartilage ossification typical of females, with one appearing in the mid-50s and becoming well developed and relatively dense only after the age of 65. Stewart and McCormick (1984:765) state that "recognition of this form of costal cartilage ossification would appear to allow for the absolute determination of female sex and strongly indicate an advanced age with a very high degree of precision, exceeding any technique previously described." In addition, they note that "Spherical or globular foci of ossification occurring in the subperichondrial location in the central portion of the costal cartilages are a feature unique to elderly women. Typically, these globular foci have smooth, rounded contours, contrast sharply with surrounding cartilage, and are centrally relatively radiolucent. We have arbitrarily called this pattern Type A."

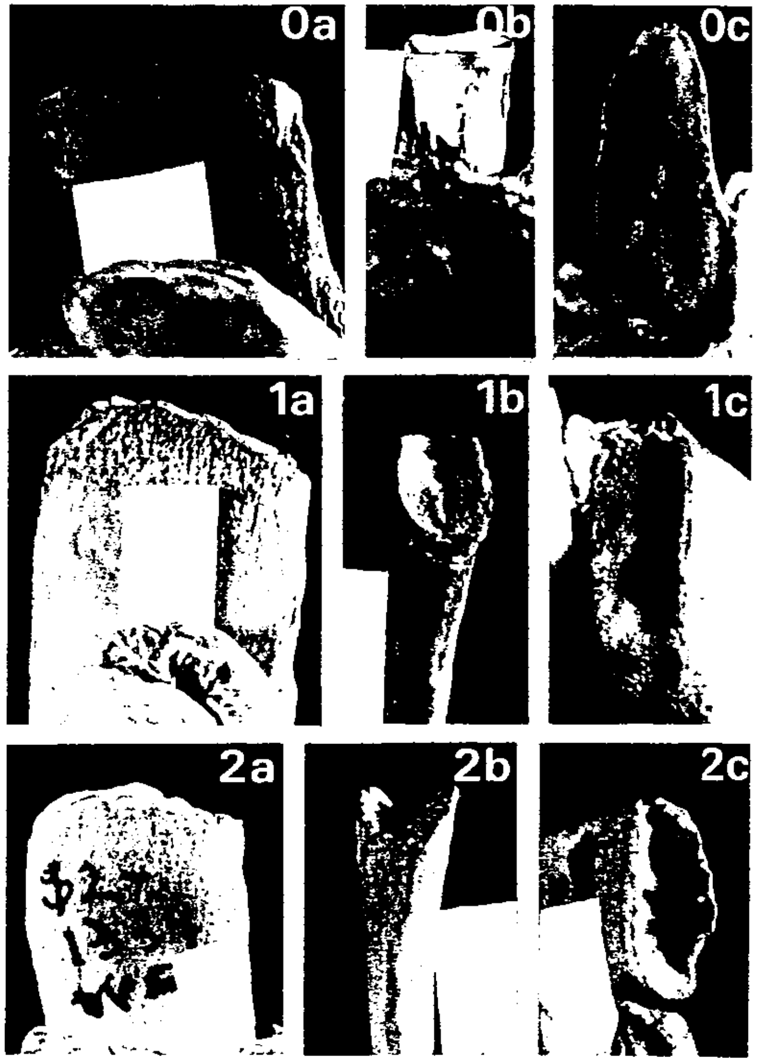


Figure 81. Model standards of phases 0–2 of sternal-end ossification of the fourth rib in white females (from Iscan *et al.* 1985:Plate 1; courtesy of S. Loth). Phase 0—The regular, rounded rim of the articular end is bordered externally by a bony overlay (0a and 0b). The medial surface of the juvenile rib is ridged or billowy with no pit formation (0c). Phase 1—The still smooth , rounded rim is now slightly more wavy (1a). Initial pit indentation can be seen in 1b and 1c, with billowing still present on the articular surface. Phase 2 (ages 15.5–19.3)—The rounded, wavy rim is first beginning to show some scallops forming at the edge (2a). A side view of the now V-shaped pit is seen in 2b, while 2c illustrates the deepening pit surrounded by thick, smooth walls. Ages based on a 95% confidence interval (from Iscan *et al.* 1985:Table 2).

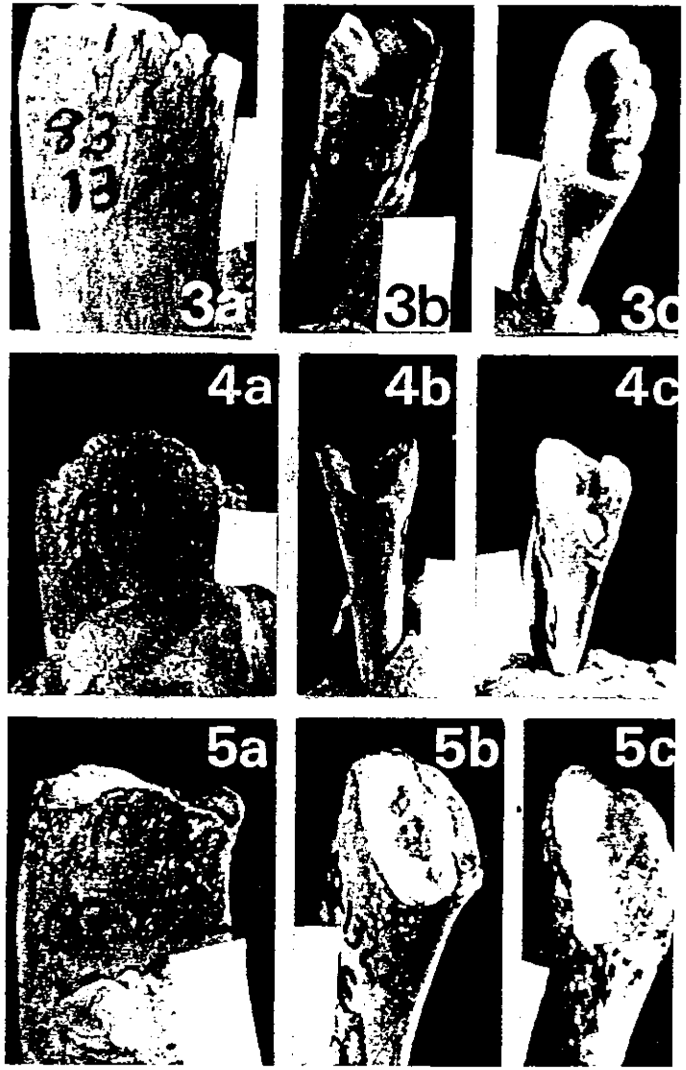


Figure 82. Model standards of phases 3–5 of the sternal-end ossification of the fourth rib in white females (from Iscan *et al.* 1985:Plate 2; courtesy of S. Loth). Phase 3 (ages 20.5–24.7)—The rounded rim now exhibits a pronounced, regular scalloped pattern (3a). The still V-shaped pit has widened as the walls flare and thin slightly, but there is only a modest, if any, increase in depth (3b and 3c). Phase 4 (ages 24.4–31.0)—4a clearly shows the central arc. Scallops remain at the still rounded rim, but the divisions are not as pronounced, and the edges look somewhat worn down. The noticeably deeper, flared V- or U-shaped pit has widened again as the walls become thinner (4b). Figure 4c shows a small plaque-like deposit beginning to form in the pit. Phase 5 (ages 33.7–46.3)—No regular scalloping remains at the now sharpening edge of the increasingly irregular rim (5a). The central arc still is present. Note the smooth plaque-like deposit covering most of the interior of the pit, which is now a very flared V or U with appreciably thinner walls (5b and 5c). Ages based on a 95% confidence interval (from Iscan *et al.* 1985:Table 2).

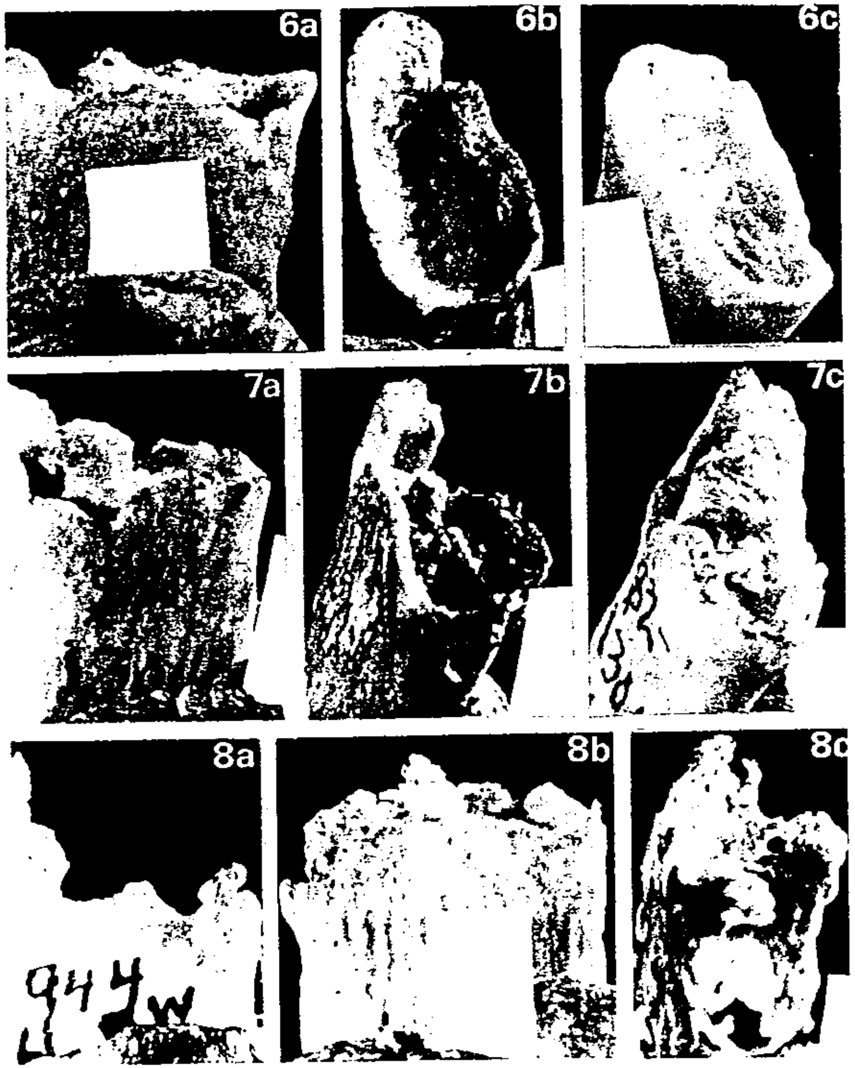


Figure 83. Model standards of phases 6–8 of sternal-end ossification of the fourth rib in white females (from Iscan *et al.* 1985:Plate 3; courtesy of S. Loth). Phase 6 (ages 43.3–58.1)—The central arc is less obvious on the sharp rim, which is starting to show irregular projections of bone (6a). 6b and 6c show the noticeably deeper and wider U-shaped pit, thinning walls, along with increased roughening and porosity inside the pit. Porosity and deterioration of bone also can be seen inside the pit. Phase 7 (ages 59.2–71.2)—7a shows the very sharp, irregular rim and nearly obscured central arc. The depth of the flared U-shaped pit appears slightly shallower than in the preceding phase. Bony projections can be seen arising from both the rim and floor of the pit, along with evident deterioration of the bone itself (7b and 7c). Phase 8 (ages 70.4–82.3)—8a shows the extremely sharp, irregular rim with brittle projections of bone now prominent at the superior and/or inferior margins of the rib. Projections also are seen extending from the floor of the pit (8b). These bony processes can be seen nearly filling the widely U-shaped pit surrounded by very thin, badly deteriorated, porous walls with "window" formation (8c). Ages based on a 95% confidence interval (from Iscan *et al.* 1985:Table 2).

Figure 84. Typical male patterns of ossification. Left illustration (A84–181) shows "Swiss-cheese"-type ossification in a 31-year-old Latin American male. The right illustration (A84–179) is the chest plate of a 64-year-old black male. Courtesy of W. F. McCormick.

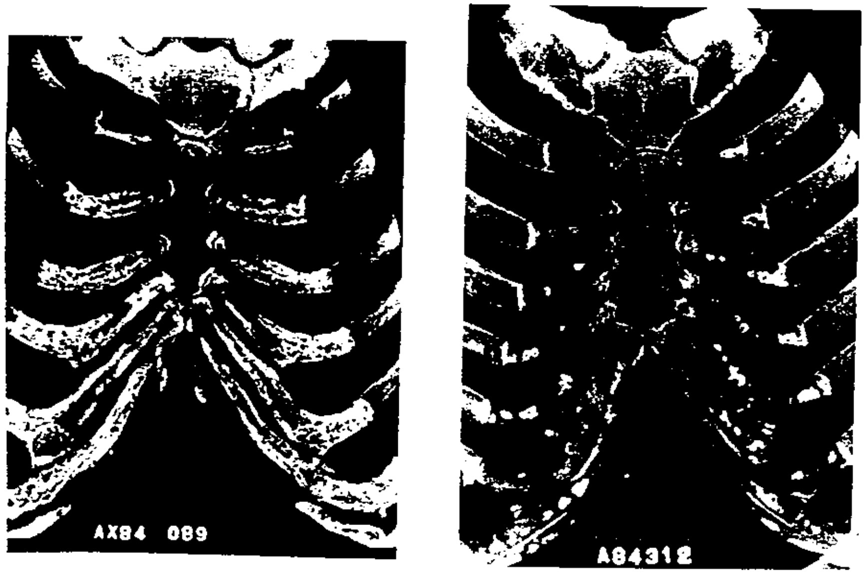


Figure 85. Typical female patterns of ossification. Left illustration (AX84–089) shows "crab-claw"-type ossification in a 64-year-old white female. Right illustration (A84–312) is the chest plate of a 69-year-old white female with a round, smooth central pattern. Courtesy of W. F. McCormick.

Humerus: Paired Long Bones (figures 86, 87)

The humerus is smaller than the femur and tibia and larger than the radius, ulna, and fibula.

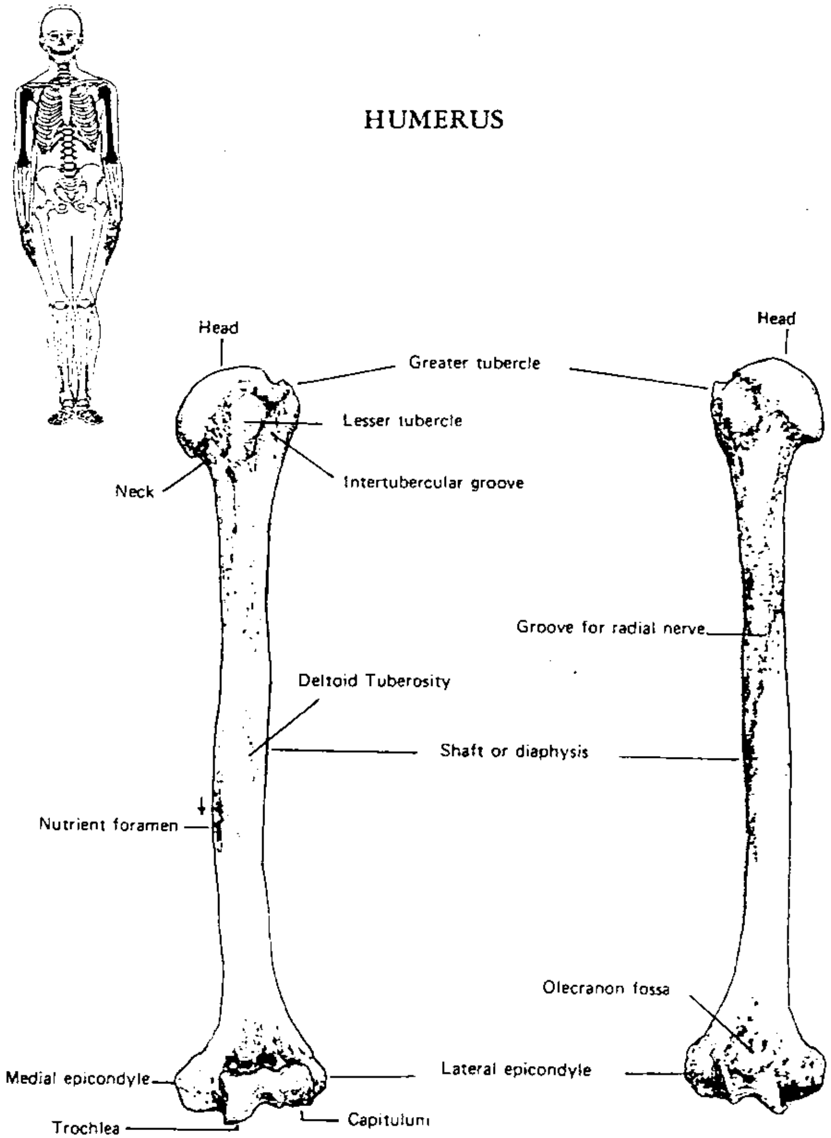


Figure 86. Characteristic features of the humerus (left bone depicted).

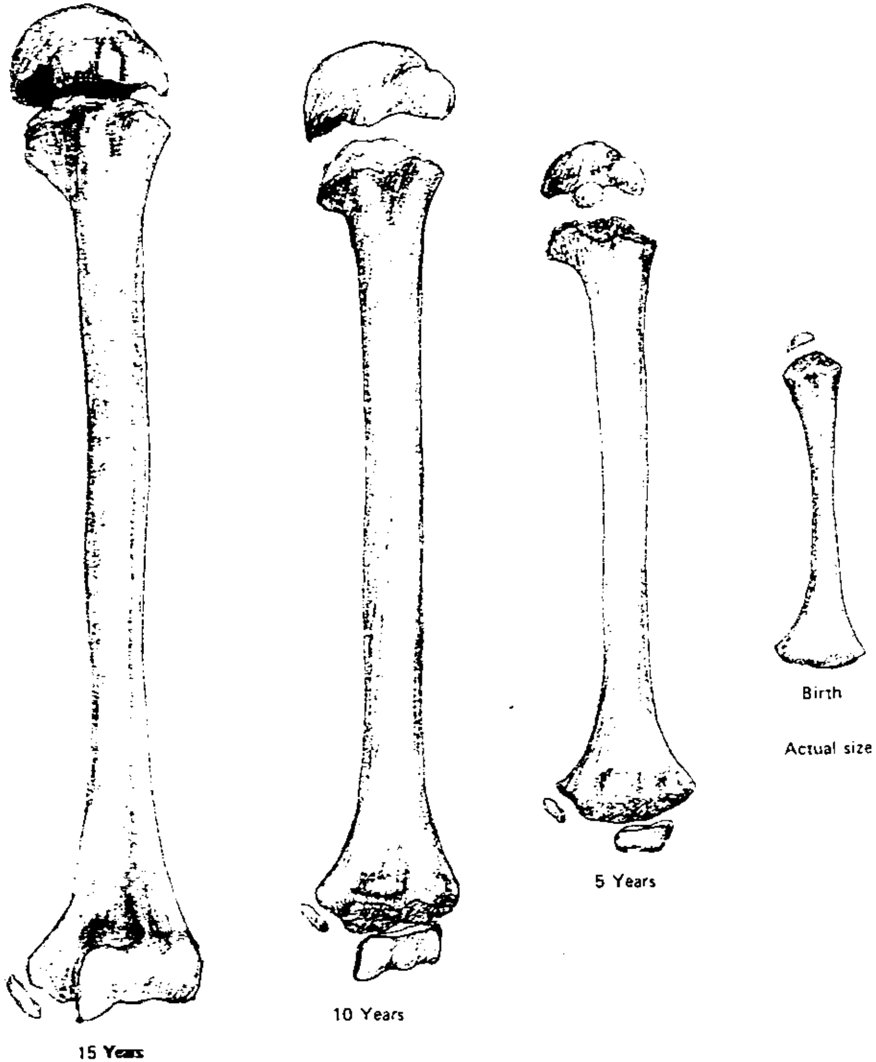


Figure 87. Developmental stages of the humerus at birth and at 5, 10, and 15 years.

Subadult Bones

The humerus ossifies from one primary center (the shaft, or diaphysis) and seven secondary centers: three in the proximal, or head, end and four in the distal end (Figure 88). The three epiphyses of the proximal end coalesce about the sixth year and fuse with the shaft about the twentieth year.

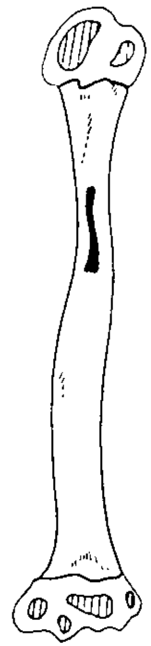


Figure 88. Ossification centers of the humerus (after Lockhart *et al.* 1959:142).

Adult Bones

The humerus is the largest and longest bone in the arm. It articulates proximally with the scapula (at the shoulder) and distally with the radius and ulna (at the elbow). The humerus is divided into (*1*) a shaft; (*2*) a proximal extremity with a head, a neck, and two tubercles (greater and lesser); and (*3*) a distal extremity with two epicondyles (medial and lateral) and articular surfaces for the radius (capitulum) and the ulna (trochlea).

The intertubercular groove extends down the lateral side of the bone and lodges the long tendon of the biceps. The nutrient foramen, or nutrient canal, is located on the medial side of the bone and in its center one-third. Note that this foramen, through which the nutrient artery enters the bone, is directed toward the distal end of the bone (Figure 89a).

The inclination of the nutrient foramen in the long bones is important in the identification of shaft fragments. If you sit in a squatting position and flex your arms so that your fists are next to your shoulders, the nutrient foramina enter the long bones of the upper and lower extremities in a direction away from the skull.

Bones of Similar Shape where Confusion May Arise

None.

Side Identification

When held in anatomical position (Figure 89b) with the head toward you and the anterior surface up, the head always is medial (inside) and is opposite the side the bone comes from. The medial epicondyle is the same. The intertubercular groove is anterior, on the lateral side of the bone, and is on the same side the bone is from. The capitulum and lateral epicondyle are the same.

When both ends of the bone are missing and you are left with only the shaft, locate the nutrient foramen and determine its inclination (always toward the distal end). Holding the distal end of the fragment, turn the shaft over so that the nutrient foramen is on the side of the bone opposite from you. The radial groove will be inclined down the bone toward the side the bone comes from (Figure 89c).

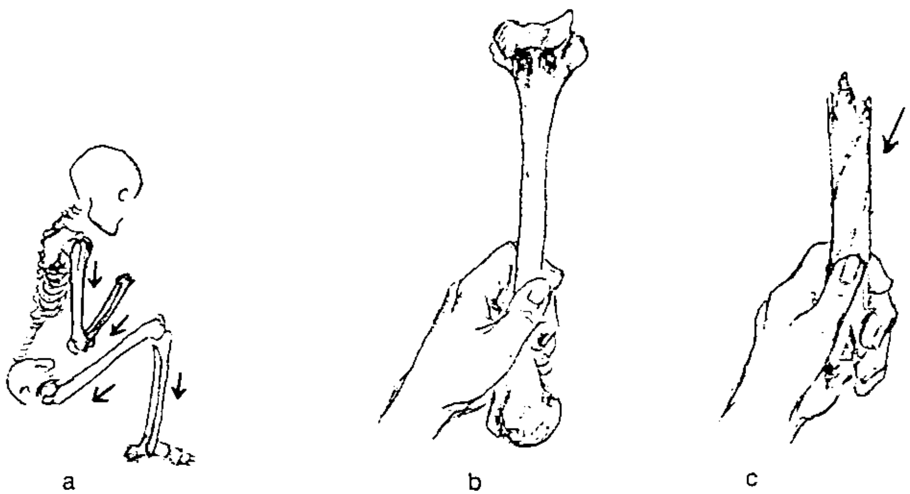


Figure 89. Side identification of the humerus using: a, direction of the nutrient foramina; b, the complete humerus; c, the diaphysis (left bone depicted).

Measurements of the Humerus (Figure 90)

1. Maximum length (osteometric board). Place the head against the fixed vertical of the board and adjust the movable upright to the distal end. Raise the bone slightly and move it up and down as well as from side to side until the maximum length is obtained (A–B).
2. Maximum diameter midshaft (sliding caliper). Locate the midpoint of the shaft on the osteometric board and mark the bone with a pencil. Measure the maximum diameter; it will be in an anteromedial direction (M–N).

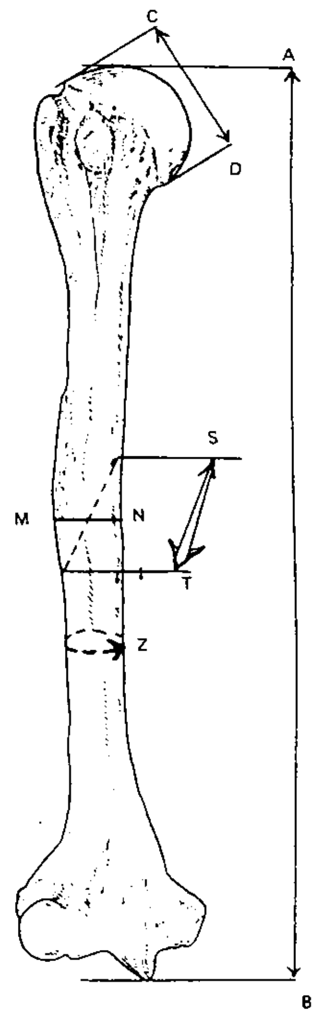


Figure 90. Landmarks for measuring the humerus.

3. Minimum diameter midshaft (sliding caliper). Taken at a right angle to the previous measurements (S–T), it is the minimum diameter of the midshaft.
4. Maximum diameter of the head (sliding caliper). Taken from a point on the edge of the articular surface of the bone across to the opposite side. The bone is rotated until the maximum distance is obtained (C–D). This measurement is used as an indicator of the sex of the individual.
5. Least circumference of the shaft (graduated steel tape). Measurement taken at about the second one-third (Z), distal to the deltoid tuberosity. It usually is located about a centimeter distal to the nutrient foramen.
6. Robusticity Index: expresses the relative size of the shaft.

$$\text{Robusticity Index} = \frac{\text{least circumference of shaft} \times 100}{\text{maximum length of humerus}}$$

7. Radiohumeral Index: expresses the relative length of the forearm to the upper arm.

$$\text{Radiohumeral Index} = \frac{\text{maximum length of radius} \times 100}{\text{maximum length of humerus}}$$

Additional Observations

At the distal end of many humeri just above the trochlea there may be a foramen extending through into the olecranon fossa that is referred to as a septal aperture (Hrdlička 1932). These septal apertures, can resemble a pinpoint, be small, medium, or large, or may be absent altogether (Figure 91). Hrdlička noted that they occur in females more frequently.

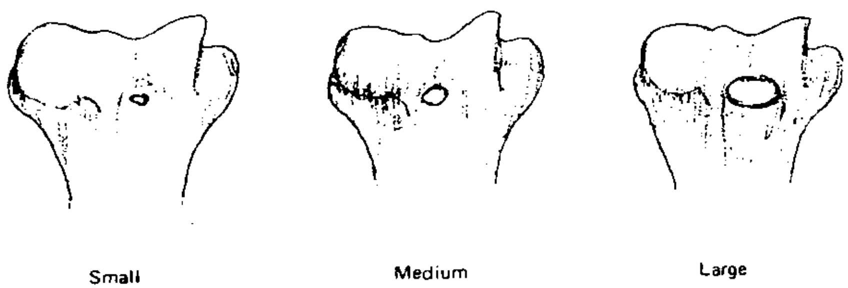


Figure 91. Types of septal apertures of the humerus.

Age Estimation

Johnston (1962) has published on the growth of long bones using data on infants and children in the Indian Knoll, Kentucky, skeletal population. The relation of age to length of subadult bone is shown in Table 25.

McKern and Stewart (1957:44) state that the epiphyses unite as follows:

Distal epiphysis: completely united by age 17–18.
Head of the humerus: completely united by age 24.
Medial epicondyle: completely united by age 19.

The medial epicondyle unites from below upward, leaving a small notch at the superior end as the last site of union (Figure 92).

Schranz (1959) radiographically studied age changes from the internal structure of the humerus based on 250 macerated humeri. Reported below are his findings beginning with age 23 (in his study he began at age 15):

23–25 years—The development of the metaphysis is accomplished. The internal structure of the epiphysis is no longer quite radial; that of the

TABLE 25.
Age Estimation from the Humerus[a]

Estimated age in years	Humerus		
	N	Mean[b]	SD[c]
Fetal	9	56.78	6.26
NB-0.5	71	67.66	5.94
0.5–1.5	42	93.14	12.11
1.5–2.5	7	113.57	5.66
2.5–3.5	11	125.64	6.86
3.5–4.5	9	136.78	5.56
4.5–5.5	6	154.67	5.42

[a]After Johnston (1962:Table 2).
[b]All measurements in mm.
[c]SD refers to the standard deviation.

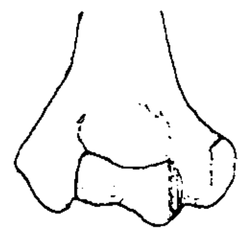


Figure 92. Medial epicondyle showing location of fusion.

diaphysis is ogival. The medullary cavity is far from the collum chirurgicum.

26–30 years—The radial arrangement of the internal structure of the epiphysis is fading. The internal structure of the diaphysis is ogival. The medullary cavity has not yet reached the collum chirurgicum.

31–40 years—The internal structure of the epiphysis has lost its earlier characteristic appearance. The internal structure of the diaphysis is more columniform. The most superior parts of the medullary cavity may approach the collum chirurgicum.

41–50—The columniform structure of the diaphysis is continuous. The cone of the medullary cavity has reached the collum chirurgicum. Between the cone and the epiphyseal line lacunae may be in evidence.

51–60—Pea-sized lacunae appear in the tuberculum majus.

61–74 years—The outer surface of the bone is rough and the cortex is thin. The diaphyseal structure lacks characteristic features. The medullary cavity has reached the epiphyseal line. Bean-sized, or even larger lacunae are present in the tuberculum majus. X-rays taken of the caput show increased transparency.

Over 75 years—The external surface of the bone is rough. The tuberculum majus has lost its prominence. The cortex is thin. Very little spongy tissue remains in the medullary cavity. In the gross specimen the epiphysis is very fragmentary. X-rays of the caput show an increased transparency.

In evaluating the above age changes it is important to know whether the bones are male or female because the changes occur at different times in the two sexes. The difference favors females and amounts to two years at puberty, 5 years at maturity, and 7–10 years in senium (Schranz 1959:275–76).

Sex Estimation

The humerus is a poor bone for sex estimation. One of the most obvious sex differences in the long bones is that typical male bones are longer and more massive than typical female bones, an expression of sexual dimorphism. However, a number of researchers have studied the humerus and present the following data in relation to sex estimation.

Diameter of the Head

In 1905 Dwight (see also Krogman 1962:144) published on the diameter in mm of the humeral head:

	Vertical	Transverse
Male	48.76	44.66
Female	42.67	36.98
Difference	6.09	5.68

Stewart (1979:100) has reported on the vertical diameter of the humeral head on dry bones for 50 males and 50 females from the Terry Collection as follows:

	Females	Sex indeterminate	Males
Vertical diameter of humeral head	<43mm	44–46mm	>47mm

Length of the Humerus

Thieme (1957:73) used length and epicondylar width of the humerus in his study of sex estimation in Negro skeletons. Although neither measurement proved to be a highly accurate indicator, his data are presented in Table 26.

TABLE 26.

Sex Estimation Using the Humerus of American Negroes[a]

Measurement	Sex	N	Mean[b]	Standard deviation	Standard error of mean	Critical ratio (t)
Humerus length	M	98	338.98	18.55	1.874	12.51
	F	100	305.89	18.66	1.866	
Epicondylar width of humerus	M	98	63.89	3.59	0.363	14.50
	F	100	56.76	3.32	0.332	

[a]After Thieme (1957:73).
[b]All measurements in mm.

According to Trotter (1934:214), a septal aperture occurs 3.7 times more frequently in females than in males. The supratrochlear foramen is one of the better group racial traits in the humerus, and its variation between the sexes also makes it a useful sex indicator. Trotter (1934:217) found the septal aperture in 4.2% of Caucasians and 12.8% of American Negroes. For the same racial groups, Hrdlička (1932:445) found 6.9% and 18.4%, respectively, and 29.6% for American Indians. According to Akabroi (1934:399), the overall average for Japanese is approximately 17%.

Ossification centers appear earlier in females, and complete union with the shaft terminates sooner than in the male. Garn *et al.* (1966:106) found that in cases where roentgenograms are involved, the relation between the capitulum of the radius and the medial epicondyle of the humerus can be used to determine sex in young specimens. There is a major sexual dimorphism, with over 70% discriminatory efficiency in their particular ossification order. They found that the ossification order is capitulum radii,

then medial epicondyle, in at least 75% of the males, while 70% of the females had the opposite order.

Based on his recent research on sexual dimorphism in the human humerus, France (1983:82–83) states that:

> [T]he best discriminating variables in determining sex are size measurements, and the best size measurements are in the proximal humerus. Unfortunately, although general size measurements have been used to identify sex and are probably appropriate for use in the population from which the discriminant analysis was tested, they will never be entirely accurate in identifying a large female from a small male. It seems from this study that there are smaller 'true' (not occupationally determined) differences between the sexes in the humerus. The proximal humerus standards, in particular, should not be applied cross-culturally, especially where occupational differences are obvious.

France (1985:97) has continued to refine the measurements and regression formulae used in his 1983 study and has supplied the following data on sex estimation of the humerus using single variables from different areas of the humerus (see figures 93 and 94 and associated information on shaded pages). In all formulae, males are larger than the "cutoff" number, and females are smaller.

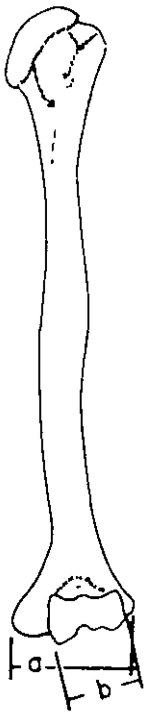


Figure 93. Measuring biepicondylar width (a) and articular width (b) on the humerus.

SEX DETERMINATION OF THE HUMERUS USING SINGLE VARIABLES FROM DIFFERENT POSITIONS ON THE BONE (AFTER FRANCE 1983:4–7, 1985)[a]

Nubian

Distal: Biepicondylar width (a)
y = 5.903 – .7875 (a)
Percent correctly identified: 89.16%, cutoff = 1.33

Distal: Articular width (b)
y = 7.279 – 1.492 (b)
Percent correctly identified: 87.76%, cutoff = 1.33

Proximal: Transverse diameter of humeral head (c)
y = 6.224 – 1.21 (c)
Percent correctly identified: 84.13%, cutoff = 1.51

Proximal: Vertical diameter of humeral head (d)
y = 6.283 – 1.176 (d)
Percent correctly identified: 91.03%, cutoff = 1.51

Diaphysial: Minimum diameter of diaphysis (e), maximum diameter of diaphysis (d)
y = 5.239 – 1.897 (e) – .474 (f)
Percent correctly identified: 76.83%, cutoff = 1.51

Negroid

Distal: Biepicondylar width (a)
y = 5.675 – .6897 (a)
Percent correctly identified: 86.55%, cutoff = 1.46

Distal: Articular width (b)
y = 5.748 – .9572 (b)
Percent correctly identified: 93.53%, cutoff = 1.46

Proximal: Transverse diameter of humeral head (c)
y = 6.130 – 1.097 (c)
Percent correctly identified: 91.88%, cutoff = 1.50

Proximal: Vertical diameter of humeral head (d)
y = 5.556 – .9067 (d)
Percent correctly identified: 89.22%, cutoff = 1.50

Diaphysial: Minimum diameter of diaphysis (e), maximum diameter of diaphysis (f)
y = 4.486 – 1.568 (e) – .869 (f)
Percent correctly identified: 84.88%, cutoff = 1.50

Caucasoid

Distal: Biepicondylar width (a)
y = 5.074 – .5983 (a)
Percent correctly identified: 85.54%, cutoff = 1.51

Distal: Articular width (b)
y = 6.051 – 1.039 (b)
Percent correctly identified: 92.12%, cutoff = 1.51

Proximal: Transverse diameter of humeral head (c)
y = 6.2132 − 1.123 (c)
Percent correctly identified: 92.31%, cutoff = 1.474

Proximal: Vertical diameter of humeral head (d)
y = 6.0223 − 1.002 (d)
Percent correctly identified: 89.37%, cutoff = 1.474

Proximal: Transverse diameter of humeral head (c), vertical diameter of humeral head (d)
y = 6.3659 − .7299 (c) − .3990 (d)
Percent correctly identified: 92.95%, cutoff = 1.474

Diaphysial: Minimum diameter of diaphysis (e), maximum diameter of diaphysis (f)
y = 4.922 − 1.3165 (e) − .5777 (f)
Percent correctly identified: 88.55%, cutoff = 1.474

Pecos Pueblo

Distal: Biepicondylar width (a)
y = 7.337 − 1.047 (a)
Percent correctly identified: 86.54%, cutoff = 1.52

Distal: Articular width (b)
y = 6.827 − 1.3559 (b)
Percent correctly identified: 87.33%, cutoff = 1.52

Distal: Biepicondylar width (a), articular width (b)
y = 7.526 − .8193 (a) − .3719 (b)
Percent correctly identified: 89.19%, cutoff = 1.52

Proximal: Transverse diameter of humeral head (c)
y = 6.475 − 1.299 (c)
Percent correctly identified: 89.63%, cutoff = 1.477

Proximal: Vertical diameter of humeral head (d)
y = 6.2388 − 1.1645 (d)
Percent correctly identified: 91.61%, cutoff = 1.477

Diaphysial: Minimum diameter of diaphysis (e), maximum diameter of diaphysis (f)
y = 3.195 − 3.177 (e) + 1.389 (f)
Percent correctly identified: 81.53%, cutoff = 1.477

Arikara

Distal: Biepicondylar width (a)
y = 7.031 − .9480 (a)
Percent correctly identified: 84.70%, cutoff = 1.51

Distal: Articular width (b)
y = 6.7195 − 1.2211 (b)
Percent correctly identified: 83.06%, cutoff = 1.51

Distal: Biepicondylar width (a), articular width (b)
y = 7.3558 − .5606 (a) − .6049 (b)
Percent correctly identified: 86.26%, cutoff = 1.51

Proximal: Transverse diameter of humeral head (c)
y = 6.9688 − 1.343 (c)
Percent correctly identified: 94.97%, cutoff = 1.48

Proximal: Vertical diameter of humeral head (d)
y = 6.5332 − 1.1509 (d)
Percent correctly identified: 90.50%, cutoff = 1.48

Diaphysial: Minimum diameter of diaphysis (e), maximum diameter of diaphysis (f)
y = 5.231 − 1.1535 (e) − .9792 (f)
Percent correctly identified: 69.4%, cutoff = 1.48

*Description of measurements is as follows.

(a) = Biepicondylar width—the distance between the most medial point on the medial epicondyle and the most lateral point on the lateral epicondyle (see Figure 93).

(b) = Articular width—measured across the anterior aspect of the articular surface from the lateral border of the capitulum to the medial border of the trochlea (see Figure 93).

(c) = Transverse diameter of the humeral head—measured by taking measurements with a sliding caliper perpendicular to the shaft of the humerus on the articular surface (see Figure 94) (after Olivier 1969).

(d) = Vertical diameter of the humeral head—measured parallel to the long axis of the shaft of the humerus on the articular surface (see Figure 94).

(e) = Minimum diameter of the diaphysis—taken where the diameter of the shaft is at its minimum, regardless of its position relative to the exact center of the long axis. The distal fixed branch of the sliding caliper is applied to the flattened surface of the shaft (usually the anteromedial surface) while the movable piece is brought into contact with the bone opposite (not illustrated).

(f) = Maximum diameter of the diaphysis—measured at the exact level of the measured minimum diameter. The maximum is measured with the stem of the caliper applied to the flattened surface of the shaft (not illustrated).

Dittrick (1979) and Dittrick and Suchey (1986) have studied sexual dimorphism of both the femur and humerus using prehistoric skeletal samples from central California. They report that the best single indicator for the humerus is the transverse diameter of the head (Figure 94). Accuracy obtained with this one measurement alone is 96% in Early Horizon, 86% in the combined Middle and Late horizons, and 88% for all horizons combined (see Table 27; Dittrick and Suchey 1986:2).

Transverse Diameter of the Head

Using a sliding caliper take measurements at right angles to the shaft. Include the ridge at the end of the articular surface if any (after Olivier 1969).

Stature Estimation

The estimation of stature from long bones has been attempted by numerous authors. However, with the humerus, radius, and ulna Trotter and Gleser (1958:120) note that "it can be stated as a general rule that in no

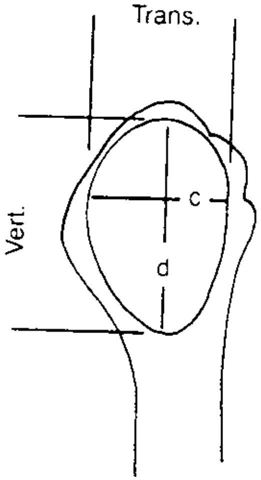


Figure 94. Measuring transverse diameter (c) and vertical diameter (d) of the head of the humerus.

TABLE 27.

Sexing by Transverse Diameter of the Head of the Humerus in Prehistoric Samples from Central California (N = 258)[a]

Sample	Male	Female	Male mean	Female mean	% Accuracy
Early Horizon	>42.8[b]	<42.8	44.5	39.6	96
Middle and Late Horizon	>40.9[c]	<40.9	43.3	38.6	86
Combined Horizon	>41.2	<41.2	43.5	38.6	88

[a]From Dittrick (1979:Table 19).[c]
[b]Measurements given in mm.
[c]Additional data courtesy of J. Suchey.

case should lengths of upper limb bones be used in the estimation of stature unless no lower limb bone is available."

Stature Formulae for the Humerus (Male)

White	2.89 humerus + 78.10 ± 4.57
Negro	2.88 humerus + 75.48 ± 4.23
Mongoloid	2.68 humerus + 83.19 ± 4.16
Mexican	2.92 humerus + 73.94 ± 4.24

Example

Given a humerus (white male) that measures 41.0 cm (410 mm):
2.89 (41.0) + 78.10 ± 4.57
118.49 + 78.10 ± 4.57

196.59 cm = mean
Range 196.59 − 4.57 = 192.02 cm (low)
196.59 + 4.57 = 201.16 cm (high)

TABLE 28.

Formulae[a] for Stature Estimation[b]

White females		Negro females	
3.36 Hum. + 57.97	± 4.45	3.08 Hum. + 64.67	± 4.25
4.74 Rad. + 54.93	± 4.24	3.67 Rad.[c] + 71.79	± 4.59
4.27 Ulna + 57.76	± 4.30	3.31 Ulna + 75.38	± 4.83
2.47 Fem.$_m$ + 54.10	± 3.72	2.28 Fem.$_m$ + 59.76	± 3.41
2.90 Tib.$_m$ + 61.53	± 3.66	2.45 Tib.$_m$ + 72.65	± 3.70
2.93 Fib. + 59.61	± 3.57	2.49 Fib. + 70.90	± 3.80
1.39(Fem.$_m$ + Tib.$_m$) + 53.20	± 3.55	1.26(Fem.$_m$ + Tib.$_m$) + 59.72	± 3.28
1.48 Fem.$_m$ + 1.28 Tib.$_m$ + 53.07	± 3.55	1.53 Fem.$_m$ + 0.96 Tib.$_m$ + 58.54	± 3.23
1.35 Hum. + 1.95 Tib.$_m$ + 52.77	± 3.67	1.08 Hum. + 1.79 Tib.$_m$ + 62.80	± 3.58
0.68 Hum. + 1.17 Fem.$_m$ + 1.15 Tib.$_m$ + 50.12[3]	± 3.51	0.44 Hum. − 0.20 Rad. + 1.46 Fem.$_m$ + 0.86 Tib.$_m$ − 56.33	± 3.22

[a]After Trotter and Gleser (1952, Table 18:495).
[b]To estimate stature of older individuals subtract .06 (age in years − 30) cm.
[c]From Trotter and Gleser (1977:355).

Radius: Paired Long Bone (figures 95, 96)

Subadult Bone

The radius is ossified from a single center near the middle of the shaft that appears about the eighth week of intrauterine life (Figure 97). The distal epiphysis appears between age 1–1½ and unites in males at about age 17–18 and in females between 16–17 years of age.

The proximal epiphysis (head) appears about age 5–6 and unites between the ages of 16 and 18.

RADIUS

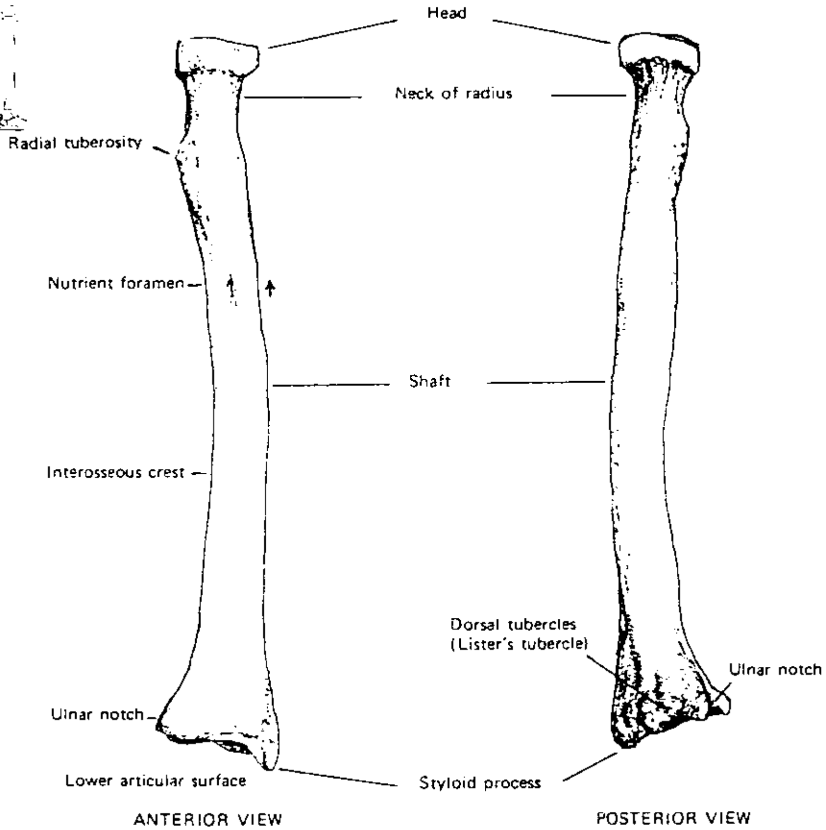


Figure 95. Characteristic features of the radius (left bone depicted).

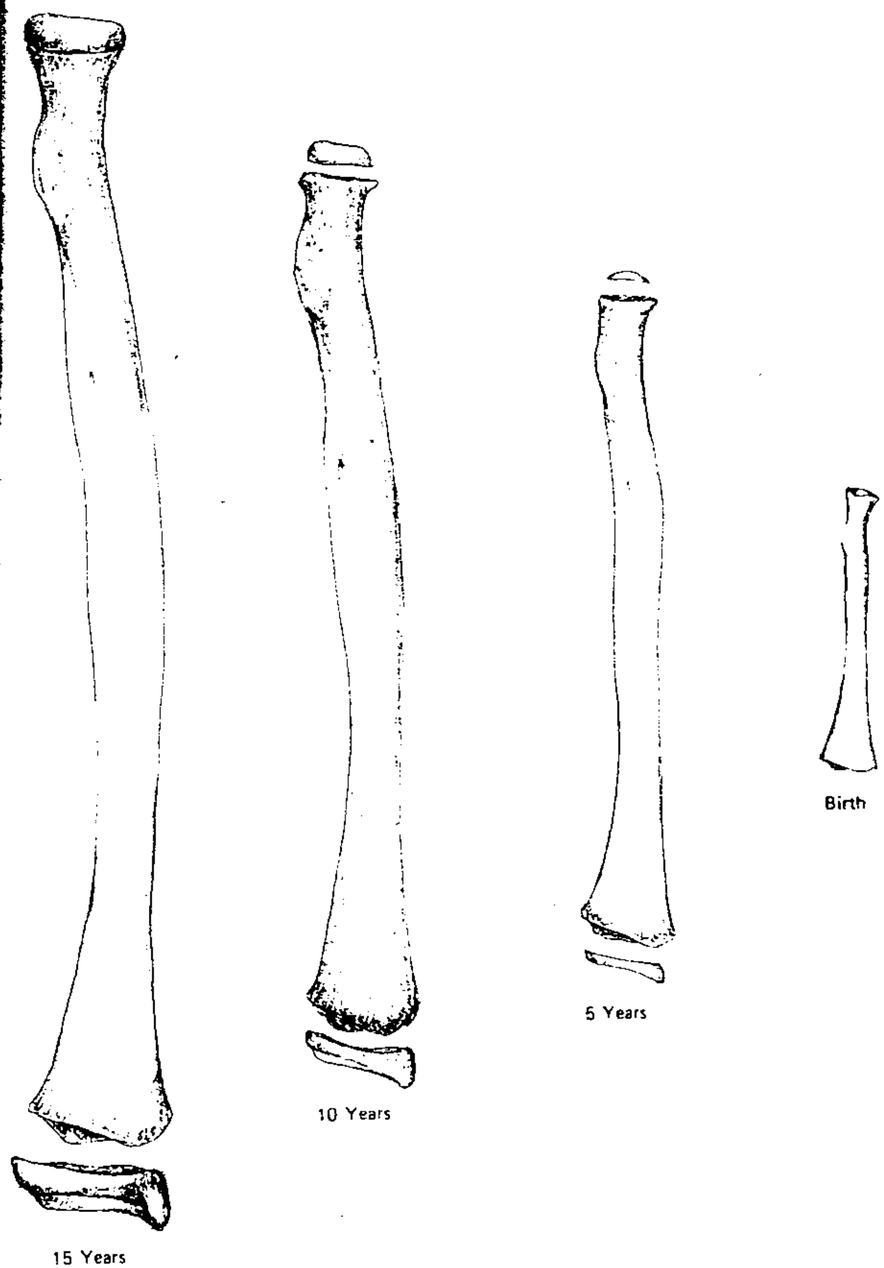


Figure 96. Developmental stages of the radius at birth and at 5, 10, and 15 years.

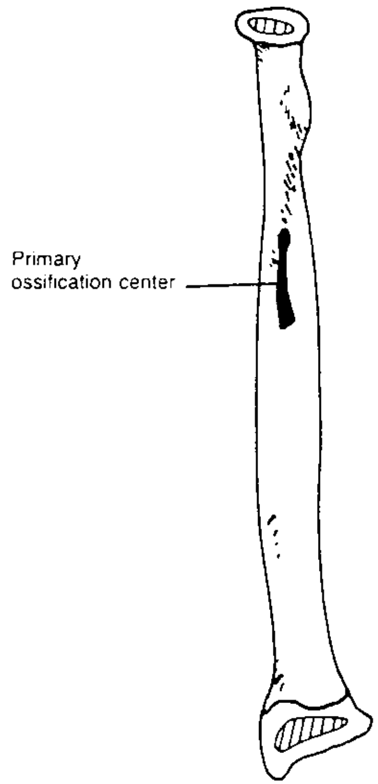


Figure 97. Primary ossification center of the radius.

Adult Bone

The radius is the lateral and shorter of the two bones of the forearm. Proximally (at the head), the radius articulates with the humerus (at the elbow), and medially with the ulna. The distal end of the radius articulates with the navicular and lunate bones of the carpus (wrist) and medially with the ulna at the ulnar notch. The proximal extremity is smaller than the distal, and the head is a circular disk forming the expanded articular end of the bone.

The distal extremity is concave for articulation with the lunate, and the styloid process articulates with the navicular bone. The medial surface contains the ulnar notch.

Note that the nutrient foramen is inclined proximally (toward the head) (Figure 89a).

Bones of Similar Shape where Confusion May Arise

The ulna and fibula are similar because of the comparable size of the shafts. The shaft of the radius is triangular with a prominent interosseous crest. The surface opposite this crest (lateral) is thick and rounded, and the triangular edges are not prominent. The ulna also has a triangular shaft with an interosseous crest, but the surface opposite the interosseous crest (medial) has sharper, more distinct edges. The shaft of the fibula tends to be irregular but more closely resembles the shaft of the ulna than it does the radius. The nutrient foramen in the ulna is larger and more prominent than in the fibula.

Side Identification

When the bone is held in approximate anatomical position with the head toward you, the nutrient foramen anterior, and the distal end away from you, the styloid process always is on the lateral side and on the side the bone is from.

The interosseous crest and the radial tuberosity always are medial and on the opposite side the bone comes from. The ulnar notch (distal end) is also medial; thus, if it occurs on the right side of the bone you are holding, it is a left bone.

Measurements of the Radius (Figure 98)

1. Maximum length (osteometric board). Measures maximum length from the head to the tip of the styloid process. Taken in same way as maximum length of the humerus (A–B).
2. Humeroradial Index: useful for comparison of the humerus and the radius.

$$\text{Humeroradial Index} = \frac{\text{maximum length of radius} \times 100}{\text{maximum length of humerus}}$$

Age Estimation

Johnston (1962) has published on the growth of long bones using data on infants and children from the Indian Knoll skeletal population. The relation of age to length of the subadult bone is shown in Table 29.

The epiphysis of the proximal end usually unites to the shaft about age 15–18. The union occurs from 2 to 4 years prior to union of the distal end, which unites in females from 16–17 and in males from 17–19 (Greulich and Pyle 1959).

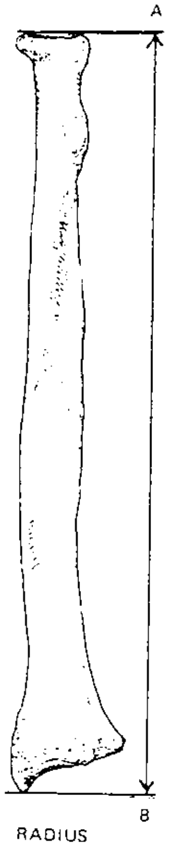


Figure 98. Landmarks for measuring the radius.

The epiphyses of the radius and ulna unite simultaneously, and the data on age of union for the radius are similar to those for the ulna. McKern and Stewart (1957:47) report that in their sample of young American Korean War dead the proximal epiphyses had all united by age 19. Early stages of union for the distal epiphyses occurred from ages 17–20 in their male sample. Last stages of union in the radius occur on the anterolateral portion of the epiphyseal line.

Sex Estimation

A number of authors have reported on the difference in the proportions of upper to lower arm lengths as expressed in the Humeroradial

TABLE 29.

Age Estimation from the Radius[a]

Estimated age in years	Radius N	Radius Mean[b]	Radius Standard deviation
Fetal	5	47.20	5.42
NB–0.5	60	55.05	4.24
0.5–1.5	24	73.96	8.36
1.5–2.5	6	91.33	4.42
2.5–3.5	7	97.86	6.47
3.5–4.5	8	108.50	2.28
4.5–5.5	5	120.00	2.76

[a]After Johnston (1962:Table 2).
[b]All measurements in mm.

Index. However, few of these measurements have been accurate enough to predict sex and race based on a single bone.

Ossification plays a major role in the sexing of the radius. The female tends to have ossification centers appearing earlier and complete union with the shaft terminating sooner than in the male. Studies by Garn *et al.* (1966:106) found that in cases where roentgenograms are involved, the relation between the radii capitulum of the radius and the medial epicondyle of the humerus can be used to estimate sex in young specimens. There is a major sexual dimorphism, with over 70% discriminatory efficiency in their particular ossification order. They found that the ossification order is capitulum radii, then medial epicondyle, in at least 75% of the males; 70% of the females had the opposite order.

Stature Estimation

As noted earlier, the lengths of upper limb bones should not be used in the estimation of stature unless no lower limb bone is available (Trotter and Gleser 1958:120). Of any of the long bones tested by Trotter and Gleser, the largest standard error of the estimate occurred with the ulna, followed by the radius.

Stature Formulae for the Radius (Male)

White	3.79 radius + 79.42 ± 4.66
Negro	3.32 radius + 85.43 ± 4.57
Mongoloid	3.54 radius + 82.00 ± 4.60
Mexican	3.55 radius + 80.71 ± 4.04

When stature is estimated for an individual over 30 years of age, the estimate should be reduced by the amount of 0.06 x (age in years − 30) cm.

Example

Given a radius (white male) that measures 23.0 cm (230mm):

3.79 (23.0) + 79.42 ± 4.66

97.17 + 79.42 ± 4.66

176.59 cm = mean

Range 176.59 − 4.66 = 171.93 cm (low)

176.59 + 4.66 = 181.25 cm (high)

Ulna: Paired Long Bone (figures 99, 100)

Subadult Bone

The ulna is ossified from a single center near the middle of the shaft that appears about the eighth week of intrauterine life (Figure 101). The distal epiphysis appears (ossifies) at age 6–7, or some 5–6 years later than the distal epiphysis of the radius. This epiphysis appears earlier than that at the proximal end but unites later—at about age 17–20.

The epiphysis at the proximal end appears at about age 11 (in the age range 7–14) and unites by the nineteenth year. Epiphyses at the elbow fuse about the eighteenth year; those at the shoulder and wrist fuse about the twentieth year.

Adult Bone

The ulna is a long bone on the medial side of the forearm, articulating at the proximal end (elbow) with the humerus and laterally with the radius. Distally, it articulates with the radius but connects only indirectly with the carpus (wrist).

The proximal extremity is of irregular shape and is the thickest and strongest part of the bone. It is useful to keep in mind the following three points regarding the proximal extremity.

The olecranon process fits into the olecranon fossa of the humerus. The semilunar notch articulates with the trochlea of the humerus. The radial notch on the lateral side of the coronoid process is for articulation with the circumference of the disk-shaped head of the radius.

The shaft, or body, of the ulna is three sided throughout much of its length but tapers near the distal extremity where it becomes smooth and rounded. The nutrient foramen is inclined toward the proximal end as in the radius (see Figure 99).

ULNA

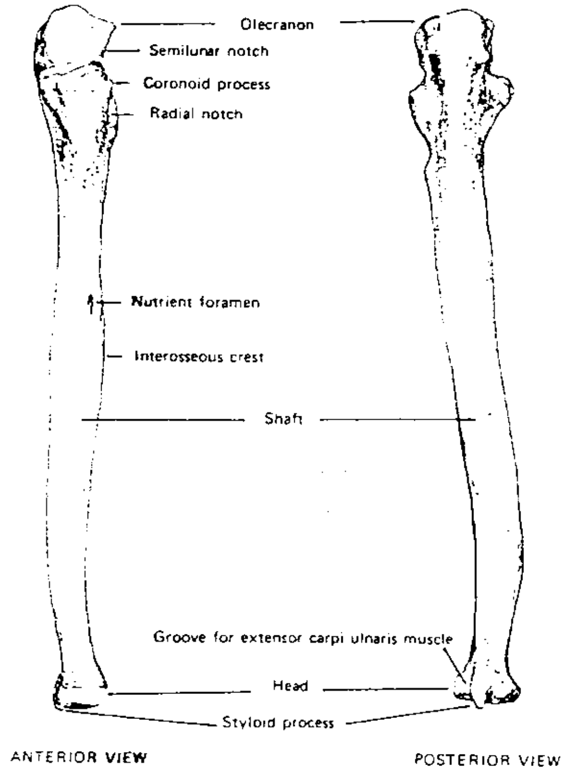


Figure 99. Characteristic features of the ulna (left bone depicted).

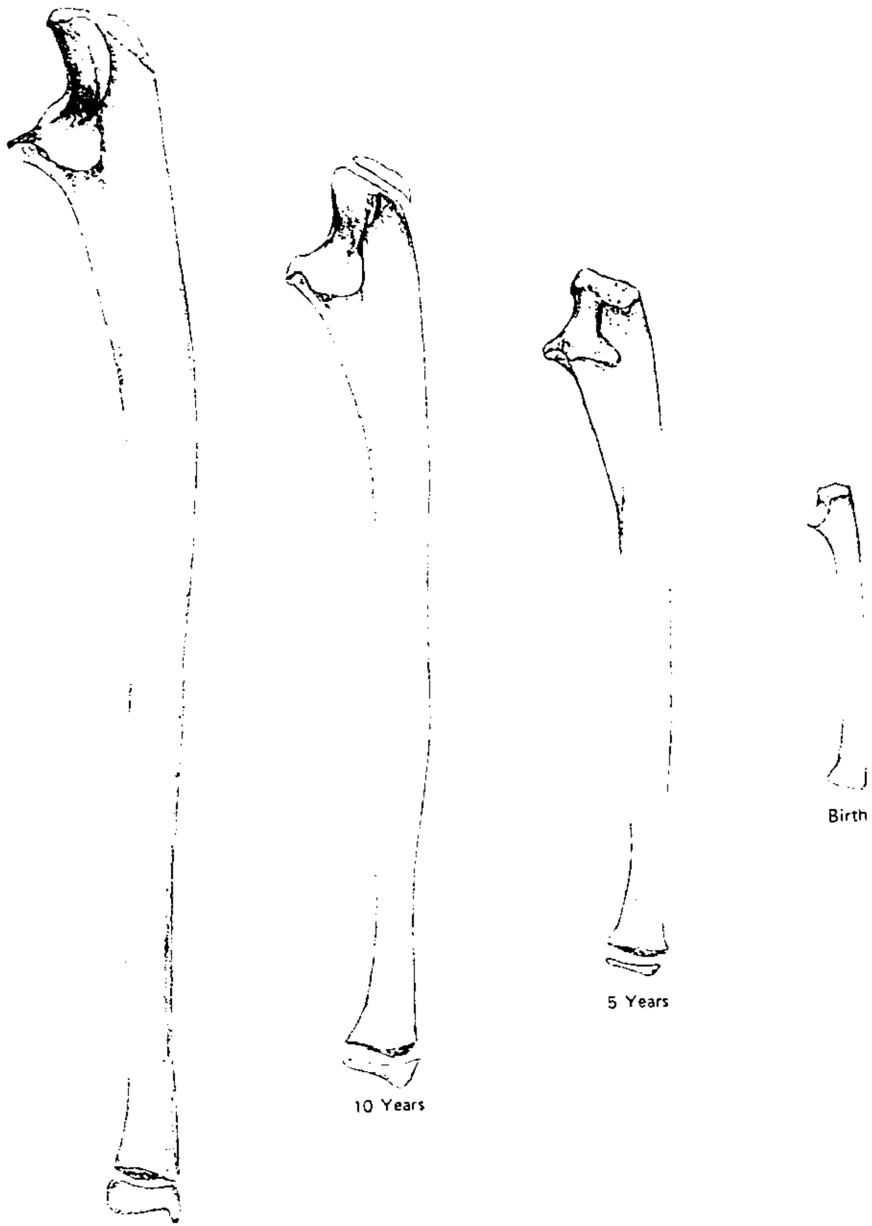


Figure 100. Developmental stages of the ulna at birth and at 5, 10, and 15 years.

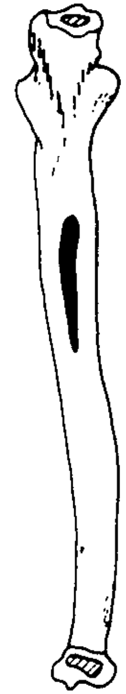


Figure 101. Primary ossification center of the ulna.

The distal extremity is small in size and consists of the anatomical "head" of the ulna. Note that this is at the opposite end of the bone from the head of the radius. The styloid process projects from the medial and posterior parts of the bone.

Bones of Similar Shape where Confusion May Arise

Because of the comparable size of their shapes, the radius and fibula often are confused with the ulna. The shaft of the radius is triangular with a prominent interosseous crest. The surface opposite this crest (lateral) is thick and rounded, and the triangular edges are not prominent. The ulna also has a triangular shaft with an interosseous crest, but the medial surface opposite this crest has sharper, more distinct edges. The shaft of the fibula tends to be irregular but more closely resembles the shaft of the ulna than it does the radius. The nutrient foramen in the ulna is larger and more prominent than in the fibula.

Side Identification

Holding the bone in approximate anatomical position with the proximal end toward you and the semilunar notch up, the radial notch (proximal end), the interosseous crest, and the nutrient foramen all will be on the side the bone is from (Figure 102a).

If you have just the distal end, hold the bone so that the styloid process is on top, and the groove for the extensor carpi ulnaris will be on the side of the styloid process that the bone is from (Figure 102b).

If you have only the shaft, locate the direction of the nutrient foramen (which is inclined proximally), and the interosseous crest always will be on the side the bone is from.

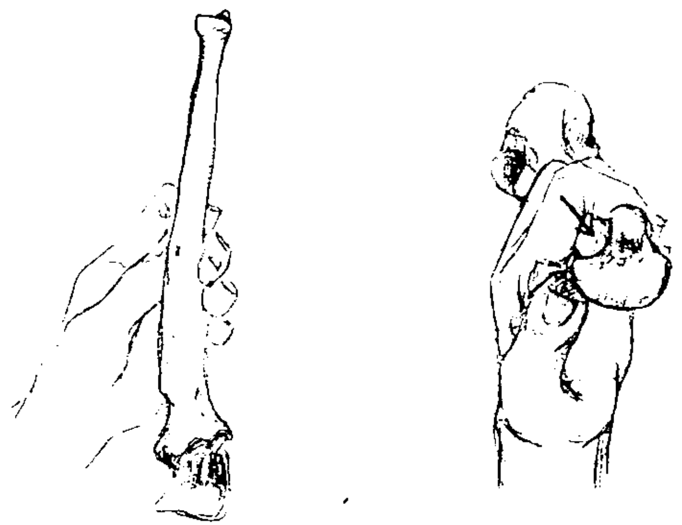


Figure 102. Side identification of the ulna using positions one (a) and two (b) described in the text (left bone depicted).

Measurements of the Ulna (Figure 103)

1. Maximum length (osteometric board). Maximum length is from the top of the olecranon process to the tip of the styloid process. Measurement is taken in the same way as that taken on the humerus (C–D).
2. Physiological length (hinge caliper). The two measuring points are (1) the deepest point on the longitudinal ridge running across the floor of the semilunar notch (A) and (2) the deepest point of the distal surface of the "head" (B), not taking the groove between it and the styloid process (A–B).
3. Least circumference of the shaft (tape). This point is located slightly above the distal epiphysis, where the shaft becomes nearly cylindrical because of the reduction of the muscular ridges and crests (E).
4. Caliber Index: expresses the relative delicacy or robustness of the bone as a whole—the greater the index, the stouter the bone.

$$\text{Caliber Index} = \frac{\text{least circumference} \times 100}{\text{physiological length}}$$

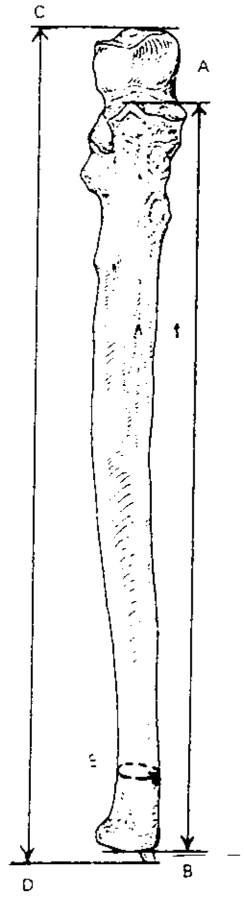


Figure 103. Landmarks for measuring the ulna.

Caliber indices of the ulna (after Wilder 1920:89):

Caliber Indices of the Ulna (after Wilder 1920:89)

	N	Index
Gibbon	4	6.0
Orang	8	10.0
Gorilla	5	13.4
Chimpanzee	2	14.3
Australians	6	12.7
Melanesians	13	13.7
Negritoes	6	14.6
South Germans	25	16.8

Age Estimation

Using data from his Indian Knoll study, Johnston (1962) studied age estimation from the ulna. The relation of age to length of the subadult bone is as follows where bone length is in mm (Table 30).

The epiphysis for the proximal end usually unites with the shaft at age 15–18 in females and by age 19 in males (McKern and Stewart 1957:47). The distal end unites in females from 15–16 years of age and in males from 17–18 (Greulich and Pyle 1959).

TABLE 30.

Age Estimation from the Ulna[a]

Estimated age in years	Ulna N	Mean[b]	Standard deviation
Fetal	5	54.80	4.12
NB–0.5	54	63.70	4.74
0.5–1.5	29	82.86	9.00
1.5–2.5	5	99.20	1.94
2.5–3.5	7	108.00	5.76
3.5–4.5	8	120.63	4.24
4.5–5.5	4	132.75	3.42

[a]After Johnston (1962:Table 2).
[b]All measurements in mm.

Sex Estimation

Although many measurements and observations have been taken on the ulna, none shows a high correlation with sex. In general, females are smaller and males are larger, but the overlap of the two populations is so great that sex estimation using the ulna has low reliability.

Stature Estimation

Only those formulae given by Trotter and Gleser (1952, 1958) will be given. The ulna usually gave the largest standard error of estimate of any of the long bones tested.

Stature Formulae for the Ulna (Male)

White	3.76 ulna + 75.55 ± 4.72
Negro	3.20 ulna + 82.77 ± 4.74
Mongoloid	3.48 ulna + 77.45 ± 4.66
Mexican	3.56 ulna + 74.56 ± 4.05

$\boxed{\text{Example}}$

Given an ulna (white male) that measures 23.0 cm (230 mm):

3.76 (23.0) + 75.55 ± 4.72

86.48 + 75.55 ± 4.72

162.03 cm = mean

Range 162.03 − 4.72 = 157.31 cm (low)

162.03 + 4.72 = 166.75 cm (high)

When stature is estimated for an individual over 30 years of age, the estimate should be reduced by the amount of 0.06 x (age in years − 30) cm.

Carpal Bones: Paired, Irregular Bones (figures 104–106)

The skeleton of the wrist consists of eight carpal bones, arranged in two rows of four. From the thumb to the little finger, the proximal, or first, row consists of:

1. Navicular, or scaphoid
2. Lunate
3. Triquetral
4. Pisiform

The distal, or second, row consists of:

1. Greater multangular, or trapezium
2. Lesser multangular, or trapezoid
3. Capitate
4. Hamate

All carpal bones except the pisiform have six surfaces. The whole of the carpus is cartilaginous at birth, and each bone is ossified from a single center.

HAND

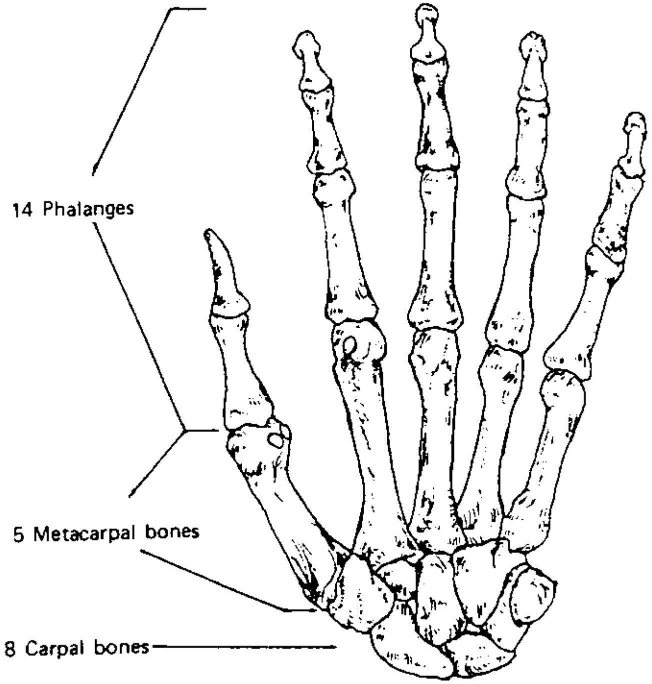


Figure 104. Elements of the hand and wrist (left hand, palm view).

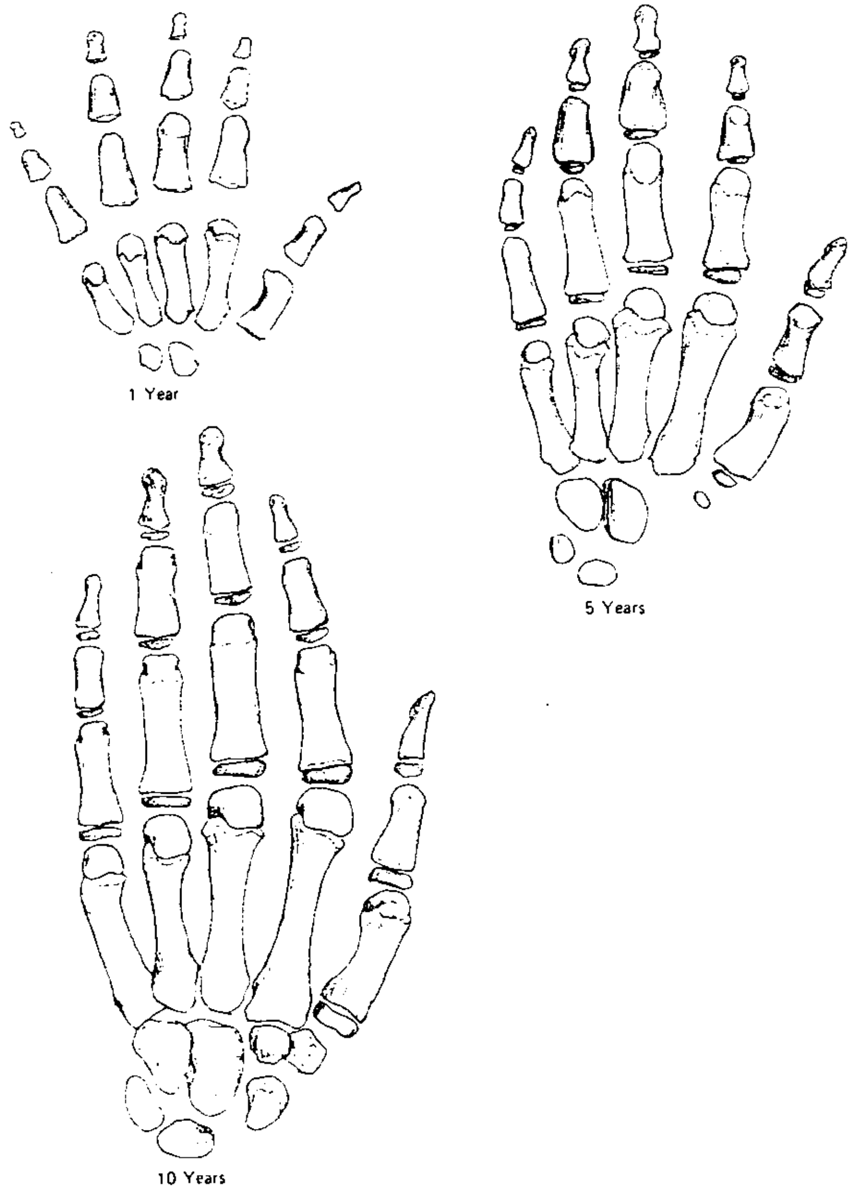


Figure 105. Developmental stages of the hand and wrist at 1, 5, and 10 years.

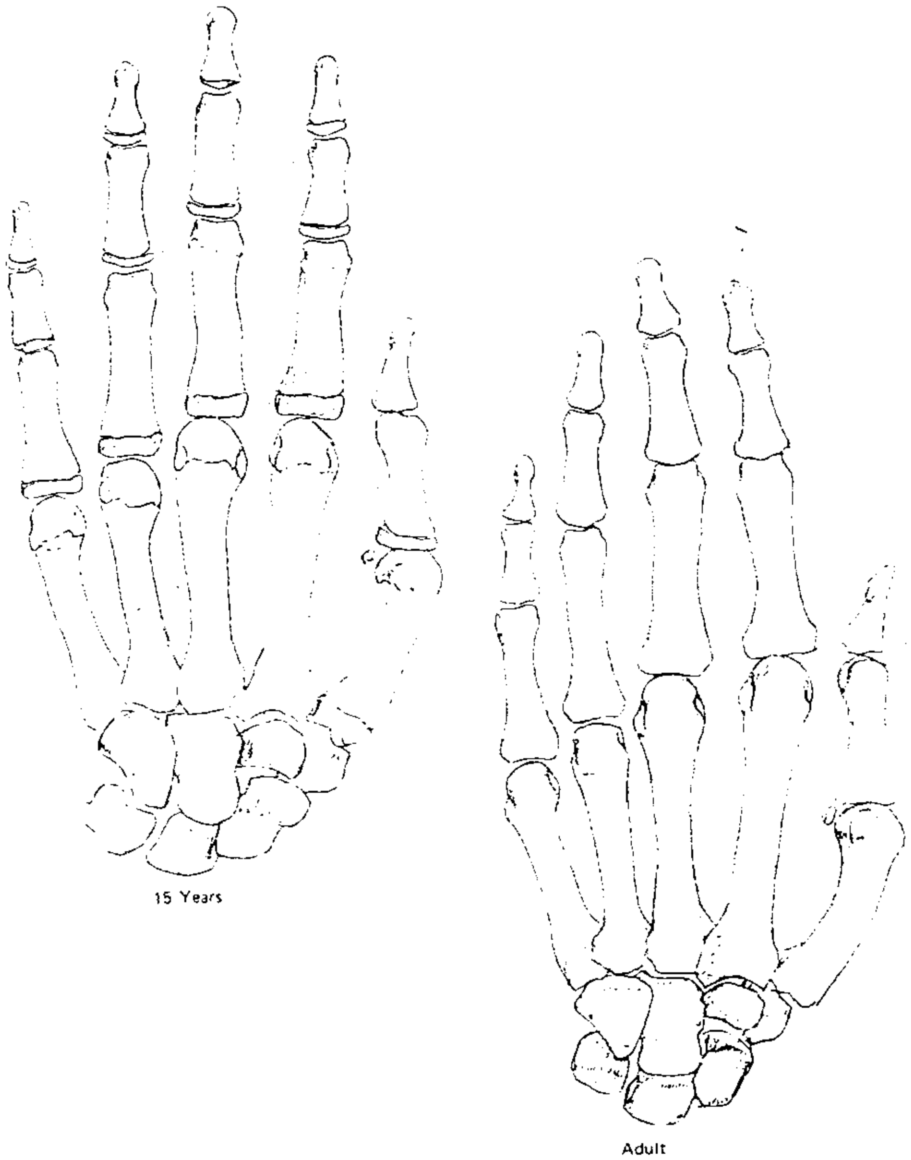


Figure 106. Developmental stages of the hand and wrist at 15 years and adulthood.

Subadult Bone

At birth in the average individual, the bones of the hand consist of the 5 metacarpals and 14 phalanges. No epiphyses are present, and none of the carpal bones has begun to ossify.

At one year in males, ossification of the capitate and hamate has begun. No epiphyses are present. In females not only the capitate and hamate have begun to ossify, but the distal epiphysis of the radius, the epiphyses of the second and third metacarpals, and the epiphyses of the proximal phalanges of the second, third, and fourth fingers now contain small, recently formed ossification centers.

At five years in males, the epiphysis for the radius is about three-fourths as wide as the distal end of the shaft. There is no epiphysis for the ulna. All carpal bones have ossified except the scaphoid (navicular) and trapezoid (lesser multangular). The epiphysis of the first metacarpal is more than half as wide as its metaphysis. The epiphyses of the metacarpals and proximal phalanges have appeared and enlarged. The epiphyses of all middle and distal phalanges have ossified.

By the age of five in females, all carpal bones have ossified. There still is no epiphysis on the distal end of the radius. All epiphyses of the metacarpals and phalanges are ossified and have expanded. The epiphyses of the middle phalanges of the second, third, and fourth fingers are shaping to the contour of the trochlear surfaces of the proximal phalanges. The distal phalanges of the third, fourth, and fifth fingers are now as wide as their shafts.

At ten years in males, the epiphyses for the radius, ulna, metacarpals, and phalanges are ossified. The epiphyses of the phalanges are almost as wide as their shafts, and those of the distal phalanges of the second to fifth fingers are wider than their shafts.

In females the ossification of all epiphyses are more advanced than in the male. The styloid process of the ulnar epiphysis is beginning to form. The epiphyses of the distal phalanges (especially the third finger) have begun to cap their shafts. In the following few years, most epiphyses of the phalanges, prior to their union with the shaft, will resemble pop-bottle caps.

At 15 years in males, the epiphysis of the radius has capped its shaft, and that of the ulna is as wide as its shaft. All carpals have now attained their early adult shape. Fusion is underway in the epiphyses of all distal phalanges.

In females, radial and ulnar epiphyses have begun to fuse with their shafts, progressing further in the ulna than in the radius. Fusion is completed or in the final stages of completion in all carpal epiphyses.

Fusion is completed first in the distal, next in the proximal, and last in the middle phalanges of the second, third, fourth, and fifth fingers. Detailed descriptions of each bone through the aging process can be found

in the *Radiographic Atlas of Skeletal Development of the Hand and Wrist* (Greulich and Pyle 1959).

Figures 107–114 present general rules for distinguishing right from left carpal bones.

The navicular (Figure 107) is the largest carpal bone of the proximal row and is the first bone of the row on the thumb side. It articulates with the lateral facet on the distal end of the radius.

To side the navicular, put your thumb in the hollow facet and your forefinger on the oval (radial) facet with the ridge side and concave portion (cutout part of the notch where the two articular facets come together) toward you. The prong points to the side it is from (articular facet for greater and lesser multangular).

The lunate (Figure 108) is the second bone in the proximal row. To side the lunate, place the flat side down. The saddle (concave articular surface for the capitate) faces you, and the facet is on the side from which it comes.

The triquetral (Figure 109), third bone from the thumb in the proximal row, is pyramidal in shape.

For siding the triquetral, note that there are three articular facets, two of which meet along a common edge (for lunate and hamate). With this edge held vertically and toward you (the thumb will be in the concave hamate facet), the third, and the only flat, facet (it joins the pisiform) is up and points toward the side from which the bone comes. The right bone fits into the left hand better, and vice versa.

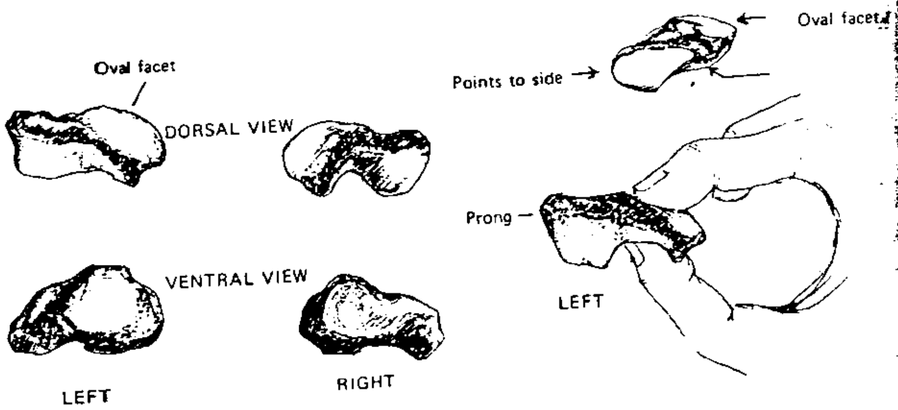


Figure 107. Characteristic features of the navicular used to side the element.

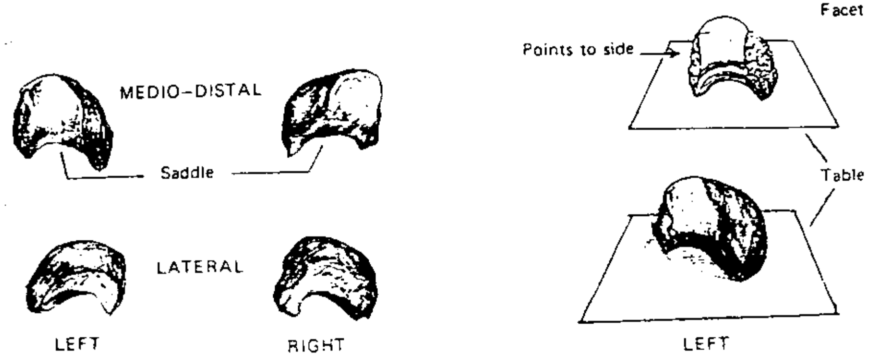


Figure 108. Characteristic features of the lunate used to side the element.

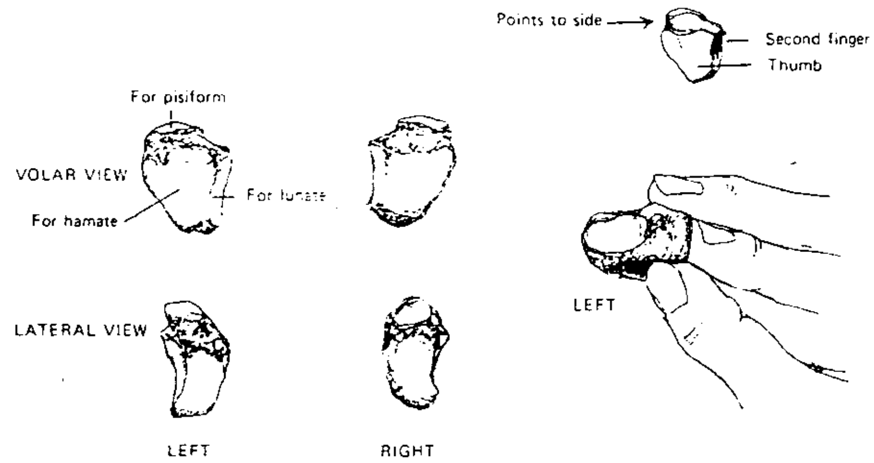


Figure 109. Characteristic features of the triquetral used to side the element.

The pisiform (Figure 110) is the smallest of the carpal bones. It is the fourth and last bone from the thumb in the proximal row. In many of its characteristics, it is in complete contrast to the other bones. It has a single articular facet, which is for the triquetral.

To side the pisiform, orient the facet on top of the bone and the tubercle away from you, and the groove or depression immediately behind the edge of the articular surface will be on the side from which the bone

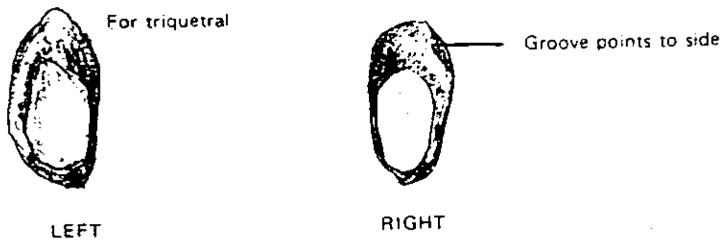


Figure 110. Characteristic features of the pisiform used to side the element.

comes. It should be noted that there is a considerable amount of variation in the pisiform, and the bone often is difficult to side.

The greater multangular (Figure 111) is the first bone on the distal carpal row, next to the thumb, and sits between the navicular and the first metacarpal.

For side identification, place the bone on a flat surface with the two large articular (saddle) facets on either side. The tubercle will be on top, away from you, and will lean or form a lip over the groove on the side from which it comes.

The lesser multangular (Figure 112) is the second and smallest of the carpal bones in the distal row.

To side the bone note that the split (nonarticular groove between articular facets for second metacarpal and greater multangular) goes

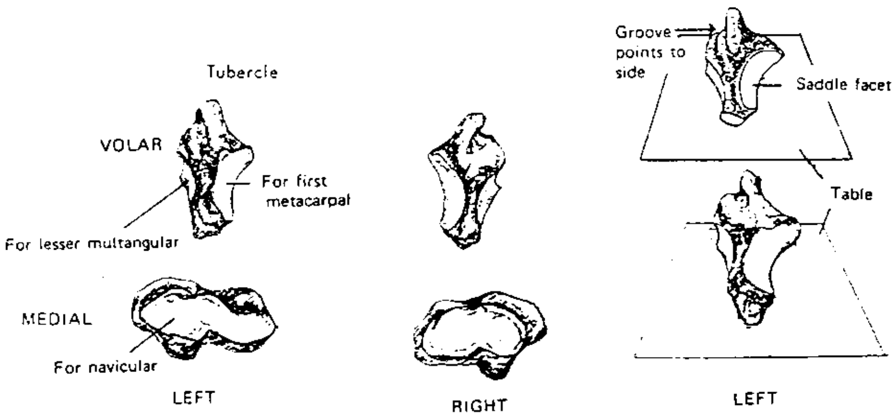


Figure 111. Characteristic features of the greater multangular used to side the element.

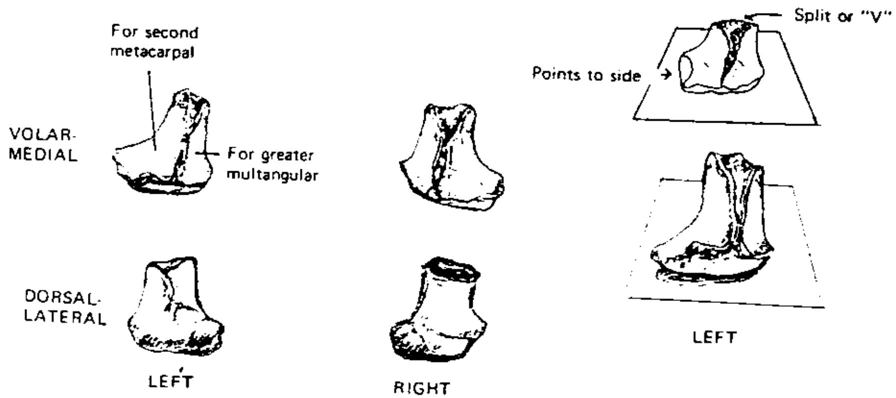


Figure 112. Characteristic features of the lesser multangular used to side the element.

toward you, and the toe points toward the side from which the bone comes. Articular surfaces are on the opposite side.

The capitate (Figure 113), situated in the center of the wrist, is the largest bone of the carpus. The rounded end is called the head.

For side identification, place the bone with the head up (proximal rounded portion) and the rough flat side toward you. The articular surface (for the hamate) narrows down toward the side from which it comes.

The hamate (Figure 114) is a wedge-shaped bone bearing a hooklike process (the hamulus). It is the fourth and last of the carpal bones in the distal row.

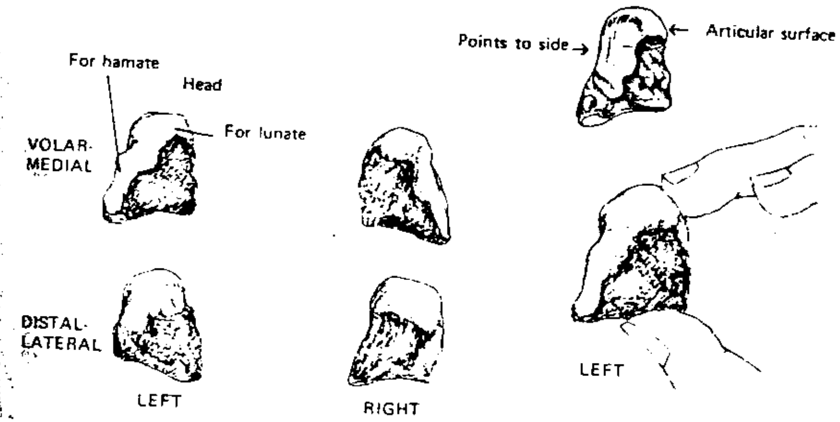


Figure 113. Characteristic features of the capitate used to side the element.

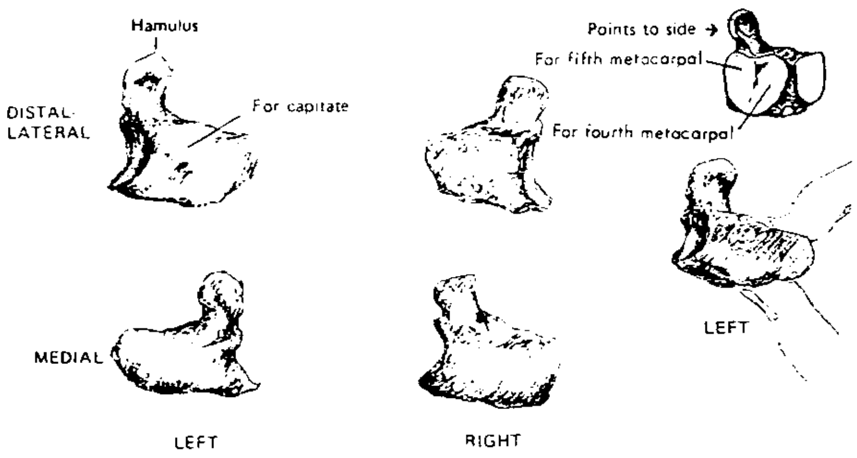


Figure 114. Characteristic features of the hamate used to side the element.

To side the hamate, place the flat (nonarticular), rough, uneven surface down and the hook (hamulus) away from you. With the large articular surface toward you, the hook is on the side from which it comes. The tip of the hamulus leans toward you.

Metacarpal Bones: Paired, Short Bones (Figure 115)

The metacarpals consist of five cylindrical bones in each hand (Figure 115). They articulate with the carpus proximally and with the first or proximal row of phalanges distally. They have been well described as long bones in miniature. As they extend from the carpus, they slightly diverge from each other. They are numbered from the lateral (or thumb) to the medial side.

As with the long bones, the metacarpals present a shaft and two extremities. The base, or carpal, extremities articulate with the carpals proximally, and except for the first metacarpal (thumb) they articulate on the side with the adjacent metacarpal bones. This is a good method of distinguishing the first from the second through the fifth.

Note that the shafts are curved so as to be slightly concave on the volar (palm) surface of the hand and thus slightly convex on the dorsal side (back). They are triangular in cross section.

The head or distal extremity articulates with the proximal (first) row of phalanges. Note that the heads all present large, rounded articular surfaces, extending farther on the volar than on the dorsal aspects. This enables one to clench one's fist. Although the nutrient foramina are

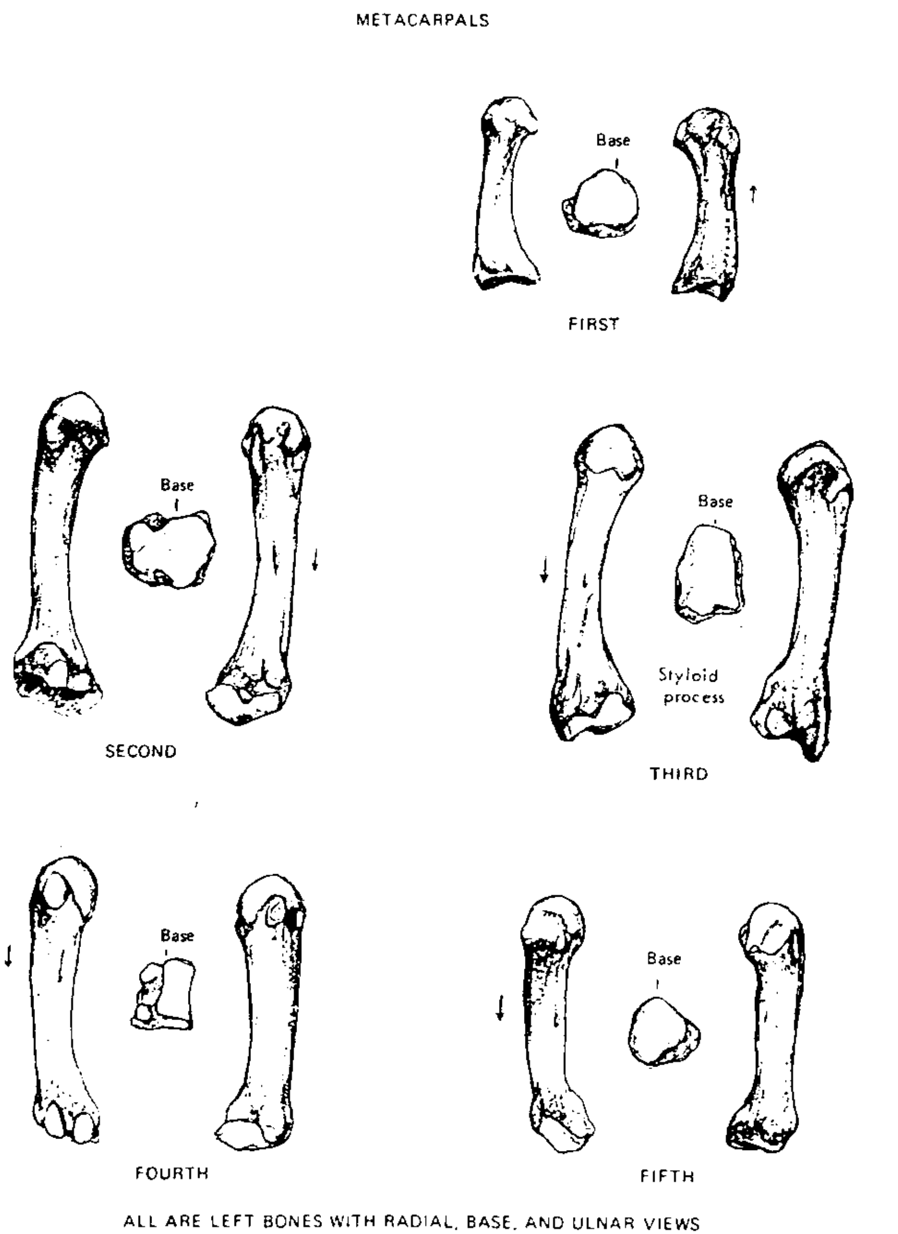


Figure 115. Characteristic features and views of the metacarpals.

difficult to find in many metacarpals, it should be noted that they are inclined toward the distal end of the first but toward the proximal end of the second through the fifth.

The first metacarpal (thumb) is the shortest and thickest of the metacarpals; it has a saddle-shaped carpal-articular surface. The second is the longest metacarpal. The third, fourth, and fifth metacarpals successively decrease in length.

Side Determination

The following description for side determination of the metacarpals is based on all the bones being held with the dorsal (back) surface toward you (Figure 116a–e).

On the first metacarpal both the proximal and distal ends project farther on the side the bone is from (Figure 116a). It has a saddle-shaped proximal-articular surface.

The proximal end of the second metacarpal projects farther on the side the bone is from (Figure 116b), and the head is inclined toward the opposite side.

The proximal end (styloid process) of the third metacarpal projects farther opposite the side the bone comes from (Figure 116c).

The entire proximal end of the fourth metacarpal is inclined toward the side the bone is from (Figure 116d).

On the fifth metacarpal, the articular facet only appears on the lateral surface of the shaft and presents an oblique line that is inclined down the bone toward the proximal end and off to the side from which the bone comes (Figure 116e).

Comparing the Metacarpals and the Metatarsals (Figure 117)

There are five metacarpals in the hand and five metatarsals in the foot.

The metatarsals are longer, and the shafts (except for the first) are a little thinner than the metacarpals.

The articular surfaces on the heads of the metatarsals are restricted laterally and are well marked anteriorly–posteriorly. This gives the appearance of having a groove causing a double expansion of the head.

The grooves between the articular facets on the proximal ends of the metatarsals are much more pronounced. They are deeper and more rugged than on the metacarpals.

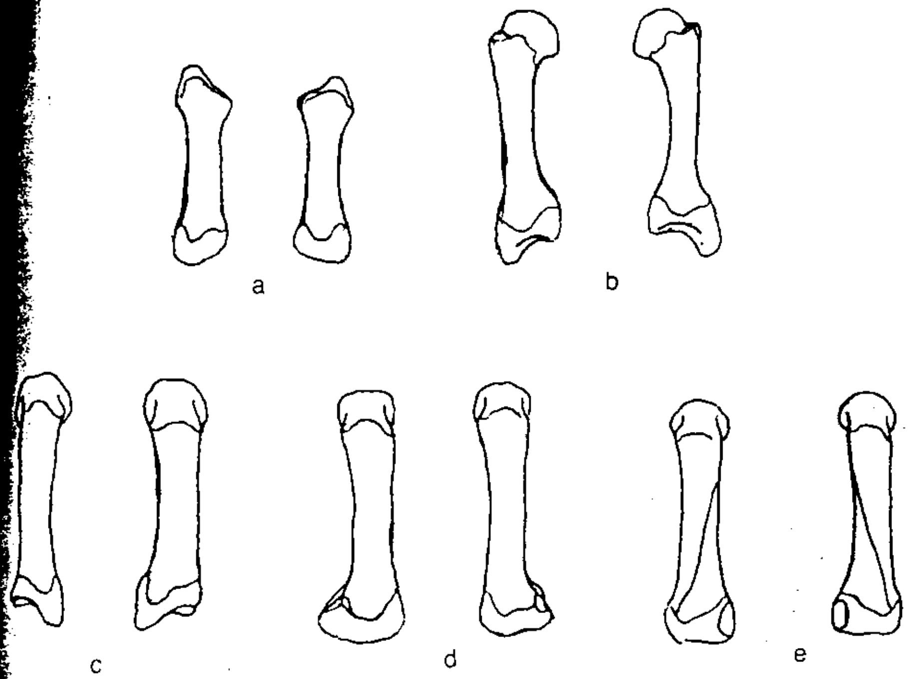


Figure 116. Side determination of the metacarpals: a, first metacarpal; b, second metacarpal; c, third metacarpal; d, fourth metacarpal; e, fifth metacarpal.

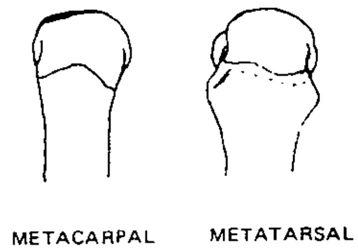


Figure 117. Morphological differences between metacarpal and metatarsal bones.

Phalanges (Fingers): Paired, Short Bones (Figure 118)

There are 14 phalanges in each hand, 2 for the thumb and 3 for each of the other digits (see Figure 104). They are divided into 3 rows (Figure 118). The first, or proximal, row has 5 phalanges; these are the largest. The second, or middle, row has 4 phalanges (the thumb has no middle phalanx). The third, distal, or terminal, row has 5 phalanges, and these are the smallest.

In all phalanges, the nutrient foramen is directed toward the distal extremity. They are not seen easily. The phalanges present a shaft and 2 extremities.

First, or proximal row—The proximal (metacarpal) extremity presents a single concave–oval articular surface that receives the convex head of the metacarpal bone. The distal extremity is grooved in the center and elevated on each side into two small condyles. When the hand is closed, the distal ends of the proximal and middle phalanges are uncovered and can be felt. The two small condyles on the distal extremity of the proximal and middle phalanges resemble the lower end of the femur. To correspond with these condyles, the bases of the terminal and middle phalanges have two small depressions and resemble the proximal end of the tibia.

Second, or middle row—The base (proximal) extremity presents two shallow depressions separated by a medial ridge. The distal end articulates with the base of the third phalanx and is grooved in the center and elevated on each side into two small condyles.

Third, or distal row—Small in size, they are recognized easily because the distal end is tapered (they are neither weight bearing nor force transmitting). The dorsal side is smooth over which the fingernail fits, and the volar is rough because of the attachment of the fiber bands that attach the finger pad to it.

The proximal end is similar in shape to that of the second phalanx in that it presents two shallow depressions separated by a medial ridge. One could never confuse the phalanges of the middle and distal row. Both ends of the middle phalanges have articular surfaces, whereas only the proximal ends of the phalanges in the distal row have articular surfaces.

Comparing the Phalanges of the Hand and Foot

There are the same number of phalanges (14) in both the hand and the foot.

With the exception of the 2 phalanges of the big toe, which are larger than the 2 phalanges of the thumb, the remaining 12 phalanges of the toes are smaller and more rudimentary than the corresponding bones in the fingers.

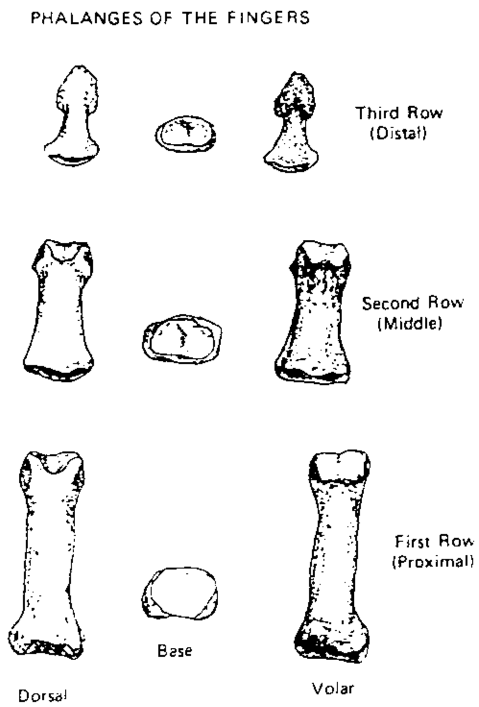


Figure 118. Phalanges of the third digit of the hand.

The phalanges of the fingers are flat on the volar (palm) surface and rounded on the dorsal surface (Figure 119).

The shaft is narrow and compressed in the phalanges of the toes, and the bones usually are not as long as in the fingers.

The nutrient foramina, which are difficult in many bones to locate, extend toward the distal end in both the fingers and toes.

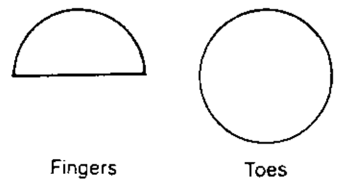


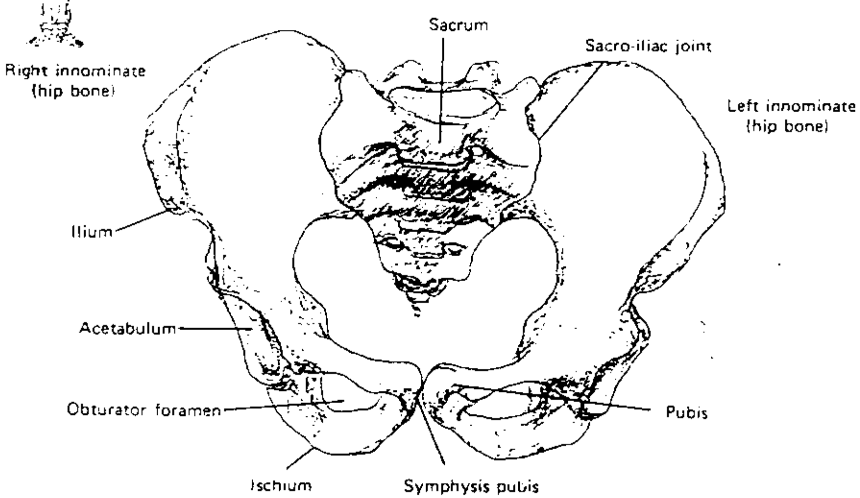
Figure 119. Morphological differences between phalanges of the hand (fingers) and foot (toes).

Hip Bone (Innominate): Paired, Irregular Bones (Figure 120)

Subadult Bone

The hip bone, or innominate, consists of three distinctive portions that unite about the twelfth year (Figure 121). Prior to adolescence the hip bone consists of three separate bones: the ilium, for which an ossification center appears about the second or third month of intrauterine life; the ischium,

PELVIS—SACRUM



FEMALE PELVIS – VENTRAL VIEW

Figure 120. Characteristic features of the pelvis and sacrum.

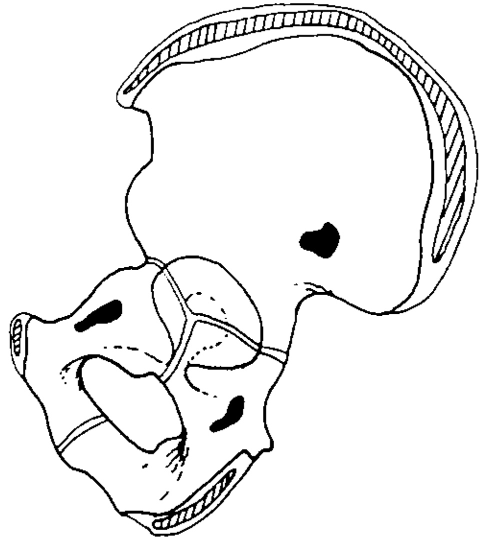


Figure 121. Ossification centers of the innominate.

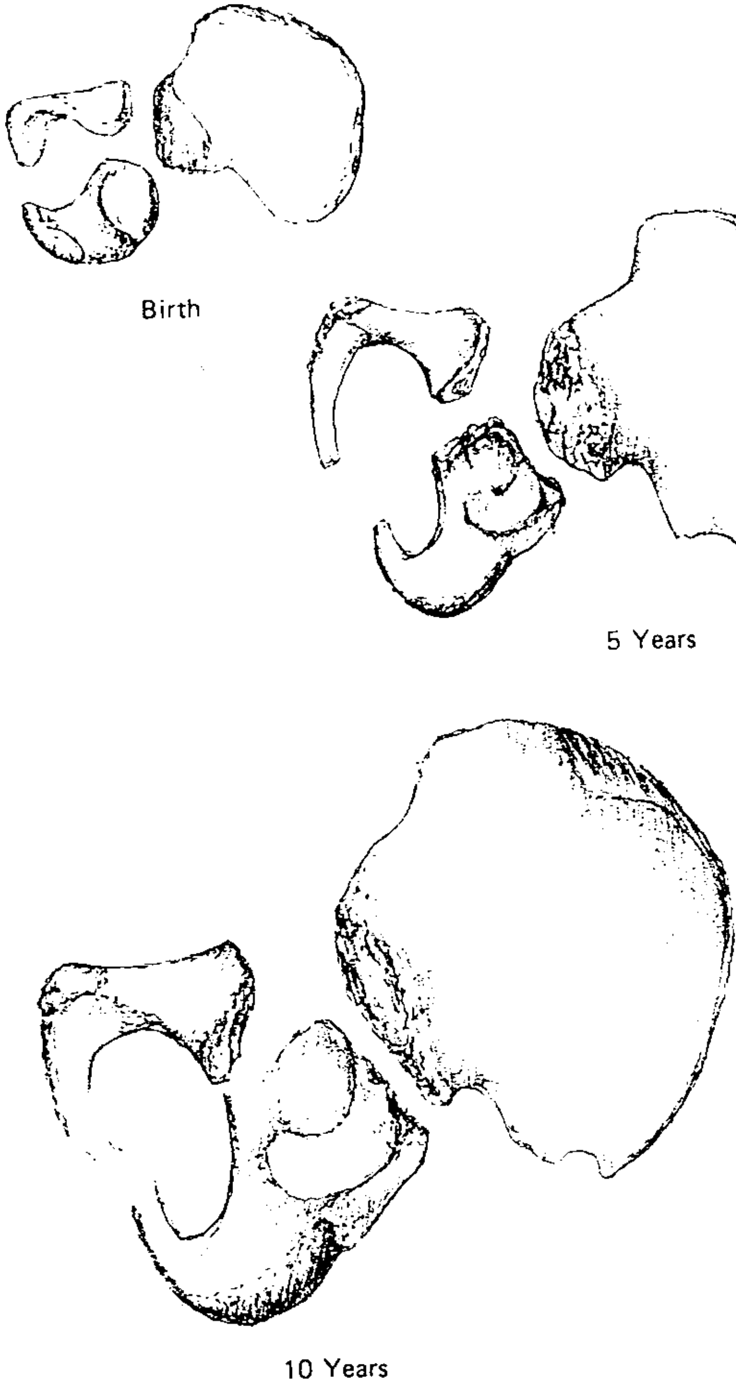
which ossifies about the fourth month; and the pubis, which ossifies about the fifth month.

The rami of the pubis and the ischium fuse between the seventh and eighth years of life. In the twelfth year, the cartilaginous strip at the acetabulum that has separated the three bones since birth begins to ossify. Complete fusion may occur as late as age 17 (Figure 122) (McKern and Stewart 1957:57).

Epiphyses, the iliac crest, the anterior–inferior iliac spine, the pubis, and the ischial tuberosity appear about puberty and unite between the ages of 16–23. Union is quite variable, as pointed out by McKern and Stewart (1957). They found the iliac crest to be completely united by age 23 in males and the ischial tuberosity to be completely fused by age 24.

Adult Bone

The hip bone (figures 123, 124) is a large, irregular bone which, with its mate of the opposite side and the sacrum, form the pelvis. It sometimes is called the innominate bone because it bears no resemblance to any common object. This is one of the most difficult bones of the body for



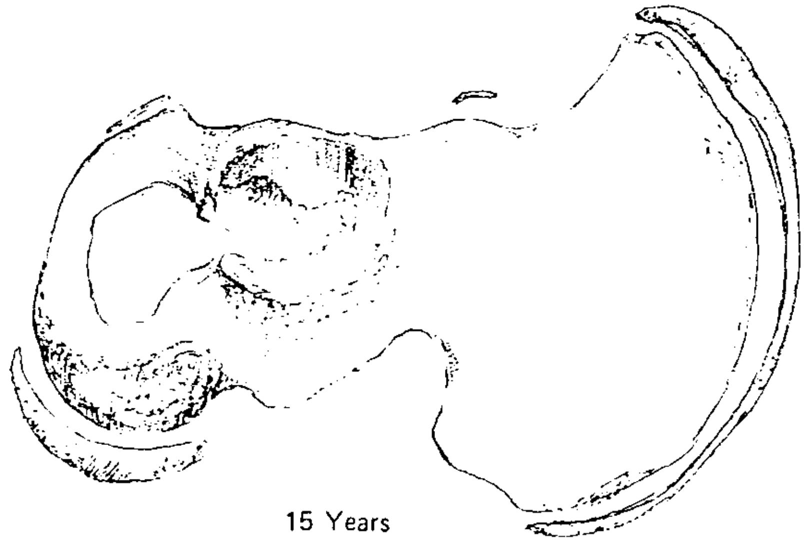


Figure 122. Developmental stages of the innominate at birth and at 5, 10, and 15 years.

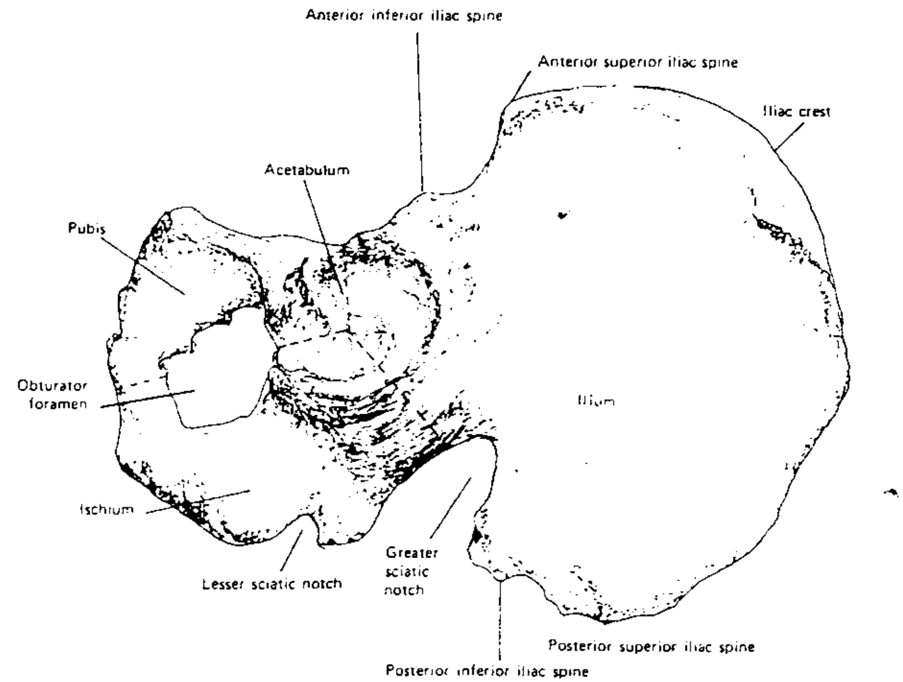


Figure 123. Characteristic features of the innominate (lateral view). Broken lines indicate schematically the lines of union of the three parts of the innominate.

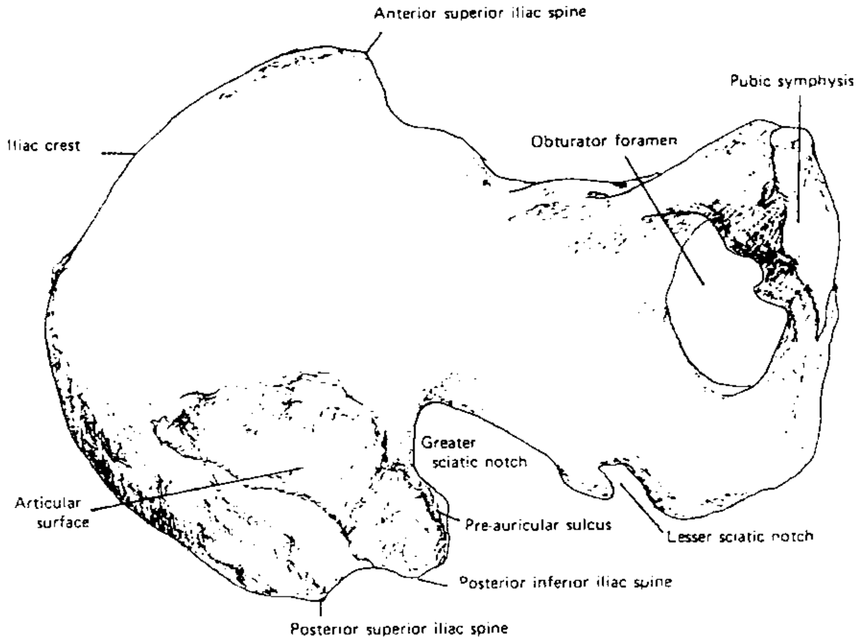


Figure 124. Characteristic features of the innominate (medial view of the left bone).

students to learn. It is difficult to orient properly, and there are a number of spines, foramina, and notches to be learned. If the proper orientation of the bone is learned, there should be little difficulty in side determination.

Each bone consists of three parts which, though separate in early life, are united into one bone in adulthood:

1. Ilium—upper portion of hip bone.
2. Ischium—lower portion of hip bone; supports the body in sitting position.
2. Pubis—anterior portion of hip bone; articulates with the opposite hip bone at the anterior midline of the body at the pubic symphysis.

The three separate bones join into the formation of the acetabulum (joint for the femur), with the ilium and ischium contributing approximately two-fifths each and the pubis one-fifth of the acetabulum (see lateral view of hip bone). Note that the acetabulum has both articular and nonarticular portions.

Bones of Similar Shape where Confusion May Arise

Scapula and flat bones of the skull. The scapula most often is thinner and presents sharper borders. Students sometimes mistake a fragmentary ilium for the flat bones of the skull. Remember that the cranial bones have suture lines; these are not found in the hip bone.

Side Identification

Holding the bone in approximate anatomical position, the ilium will be posterior, the pubis anterior, and the greater sciatic notch down (inferior). The acetabulum will be on the outside (lateral) (for the articulation of the femur), and this is on the same side the bone is from.

The articular surface of the ilium (sacroiliac joint) is inside (medial) and always is posterior to the greater sciatic notch. The preauricular sulcus (well defined in females) is just anterior to the articular surface of the ilium and is between the articular surface and the greater sciatic notch.

The pubis is smooth on the medial (back) surface and is rougher on the ventral (front) surface.

Measurements of the Innominate (Figure 125)

1. Maximum height (osteometric board). Place the ischial tuberosity (or ischium) against the fixed vertical of the board and afix the movable upright to the iliac crest. Raise the bone slightly and move it up and down as well as from side to side until the maximum length is obtained (A–B) (Figure 125).
2. Maximum breadth (osteometric board or sliding caliper). The distance between the anterior–superior iliac spine to the posterior–superior iliac spine (C–D).
3. Ischium–Pubis Index: an index used by Washburn (1948) to measure easily and effectively the difference in proportion between male and female pelves. The measurement of the subpubic angle often is made for this same reason; however, both innominates are necessary for this measurement. The Ischium–Pubis Index can be calculated from a single innominate.

The length of the ischium and pubis is measured from the point at which they meet in the acetabulum (Washburn 1948:200). This meeting point is characterized by an irregularity, a change in thickness of the bone, or a notch. As Stewart (1954:418) pointed out, the location of point A is difficult. Point A represents the meeting place of the three elements that unite to form the innominate (Figure 126).

$$\text{Ischium–Pubis Index} = \frac{\text{pubis length} \times 100}{\text{ischium length}}$$

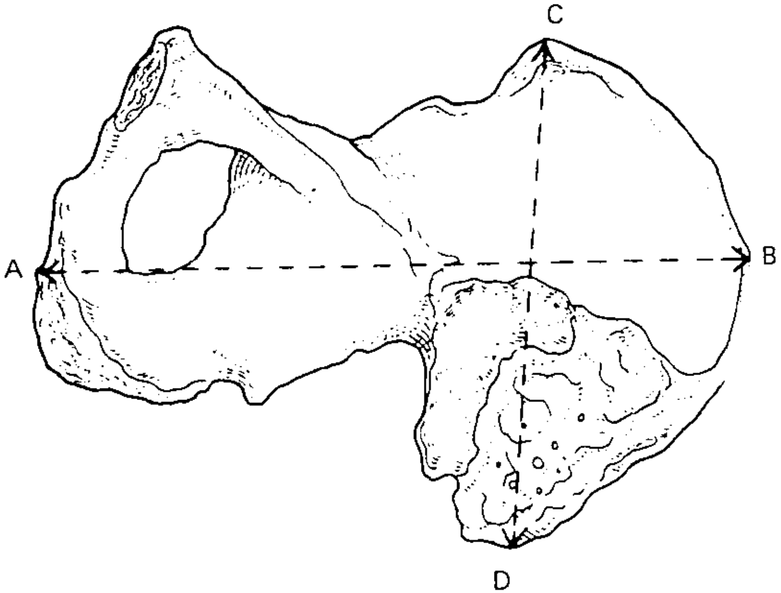


Figure 125. Landmarks for measuring the innominate.

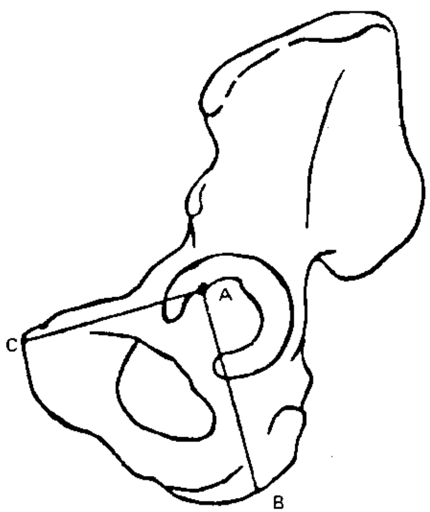


Figure 126. Landmarks for sexing the innominate. Point *A* is located in the acetabulum, the cup-shaped cavity receiving the head of the femur. This point represents the meeting place of the three elements from which the innominate is formed. The pubis is one of these elements, and its length is measured by the line *A–C*. Another of these elements is the ischium, and its length is measured by the line *A–B*. The sex of the specimen is indicated by the relation of these two lines, according to a formula given in the accompanying text (after Schultz 1930).

The Ischium–Pubis Index aids in sex estimation, according to its position as follows:

Whites (N = 200)	Negroes (N = 100)
Below 90 = male	Below 84 = male
90–95 = sex indeterminate	84–88 = sex indeterminate
95+ = female	88+ = female

This index averages 15% higher in females than in males (Washburn 1948:206). Montague (1960:629) offers the following information concerning statistics for this index according to sex:

	Mean	Range
White male	83.6±4.0	73–94
White female	99.5±5.1	91–115
Negro male	79.9±4.0	71–88
Negro female	95.0±4.6	84–106

Age Estimation

The innominate is probably the most important bone in age estimation because the changes occurring in the development of subadult bone to adult bone in the pubic symphysis are very distinct.

Pubic Symphysis

Following the union of the epiphyses, one of the best areas to determine age of an adult is from the pubic symphysis, the adjoining areas where the two hip bones join in front. Todd (1920) observed that the symphyseal face of the pubic bone undergoes a regular metamorphosis from puberty onward. He established 10 phases of pubic-symphysis age, ranging from 18 to 50+ years (Figure 127). These phases are defined as follows (Todd 1920:301–13):

First postadolescent: 18–19 years—Symphyseal surface rugged, traversed by horizontal ridges separated by well-marked grooves; no ossific nodules fusing with the surface; no definite delimiting margin; no definition of extremities.

Second postadolescent: 20–21 years—Symphyseal surface still rugged, traversed by horizontal ridges, the grooves between which are, however, becoming filled near the dorsal limit with a new formation of finely textured bone. This formation begins to obscure the hinder extremities of the horizontal ridges. Ossific nodules fusing with the upper symphyseal face may occur; dorsal limiting margin begins to develop, no delimitation of extremities; foreshadowing of ventral bevel.

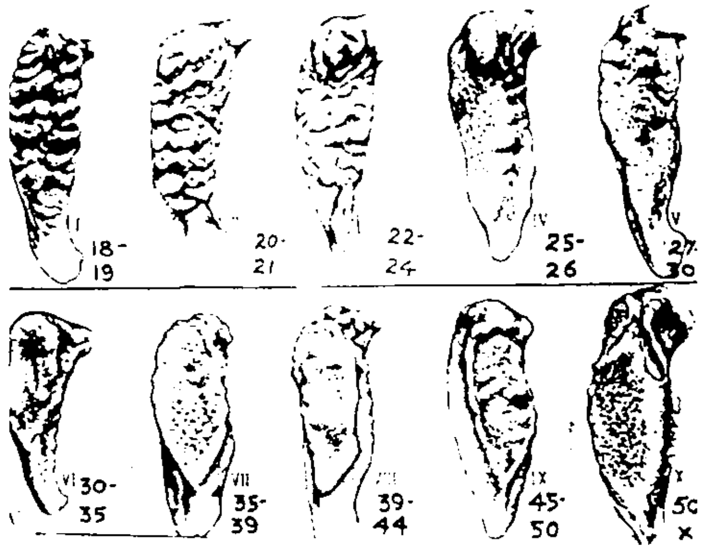


Figure 127. Model standards of Todd's 10 typical phases of age in the pubic symphysis (from Krogman 1962). Courtesy of Charles C. Thomas, publisher, Springfield, Illinois.

Third postadolescent: 22–24 years—Symphyseal face shows progressive formation of the dorsal plateau; presence of fusing ossific nodules; dorsal margin gradually becoming more defined; beveling as a result of ventral rarefaction becoming rapidly more pronounced; no delimitation of extremities.

25–26 years—Great increase of ventral beveled area; corresponding delimitation of lower extremity.

27–30 years—Little or no change in symphyseal face and dorsal plateau, except that sporadic and premature attempts at the formation of a ventral rampart occur; lower extremity, like the dorsal margin, is increasing in clearness of definition; commencing formation of upper extremity with or without the intervention of a bony (ossific) nodule.

30–35 years—More difficult to appraise correctly; essential feature is completion of oval outline of symphyseal face. More individual variation than at younger ages; terminal phases affect relatively minor details. Also, tendency for terminal phase to be cut short. Increasing definition of extremities; development and practical completion of ventral rampart; retention of granular appearance of symphyseal face and ventral aspect of pubis; absence of lipping of symphyseal margin.

35–39 years—Paramount feature: Face and ventral aspect change from granular texture to fine-grained or dense bone. Changes in symphyseal face and ventral aspect of pubis consequent upon diminishing activity; commencing bony outgrowth into attachments of tendons and ligaments, especially the gracilis tendon and sacrotuberous ligament.

39–44 years—Symphyseal face generally smooth and inactive; ventral surface of pubis also inactive; oval outline complete or approximately complete; extremities clearly defined; no distinct "rim" to symphyseal face; no marked lipping of either dorsal or ventral margin

45–50 years—Characterized by well-marked "rim." Symphyseal face presents a more or less marked rim; dorsal margin uniformly lipped; ventral margin irregularly lipped.

50 years+—Rarefaction of face and irregular ossification. Symphyseal face eroded and showing erratic ossification; ventral border more or less broken down; disfigurement increases with age.

McKern and Stewart (1957) developed a more objective system for studying the symphyseal surface, but it is complicated and difficult for the unskilled to implement. Their system should be consulted when age estimation is required.

Gilbert and McKern (1973) published a method of aging the female *Os pubis*, following the same general format and standards that were established by McKern and Stewart (1957) for aging males. Gilbert also has developed plastic models of pubic standards and has permitted reproduction of figures 1 and 2 from his 1973 article with McKern (see figures 128, 129).

Innominate

Suchey has continued her research on age estimation in males using data on the pubic symphysis and has amassed a modern multiracial sample of over 700 whites, blacks, Mexicans, and Orientals. Suchey *et al.* (1986) recommend the use of the Todd system but suggest modifications of Todd's and McKern and Stewart's systems based on recent data (Katz and Suchey 1986). Figure 130 is based on data presented in Katz and Suchey (1986) and illustrates the Suchey-Brooks male pubic-symphyseal phases (I-VI) (courtesy of J. Suchey).

Iliac Crest

Suchey and her students (e.g., Owings 1981; Webb and Suchey 1985) also have analyzed epiphyseal union of the anterior iliac crest in a modern multiracial sample of males and females (see tables 31–33).

AGING THE FEMALE *OS PUBIS*

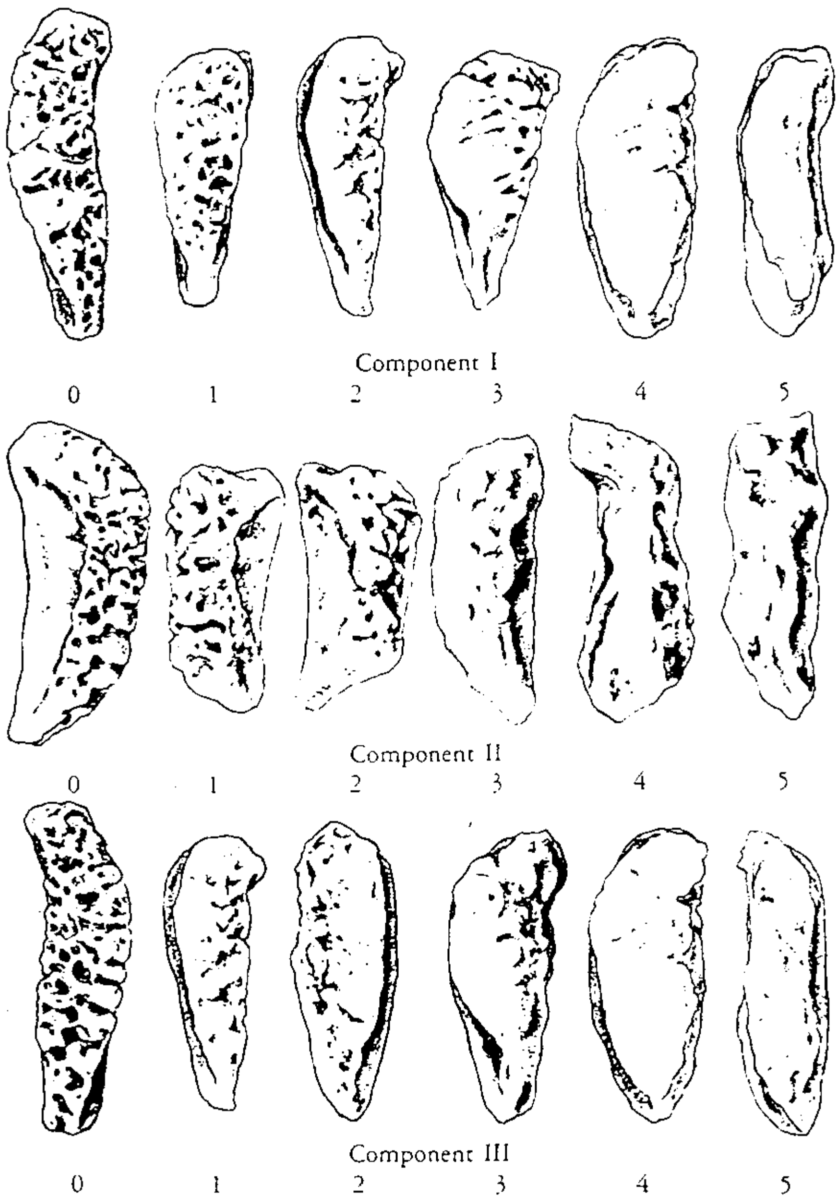


Figure 128. Medial surface of the symphysis pubis in females. All pubes depicted in Component I are of the left side; those in Component II are 0, 2, 4, right side, and 1, 3, 5, left side. Component III pubes are 0, 2, 5, right side, and 1, 3, 4, left side. Component II is tilted laterally to emphasize the ventral aspect. The medial surfaces have been tilted to emphasize the ventral aspect of the female public symphysis (from Gilbert and McKern 1973:Figure 1).

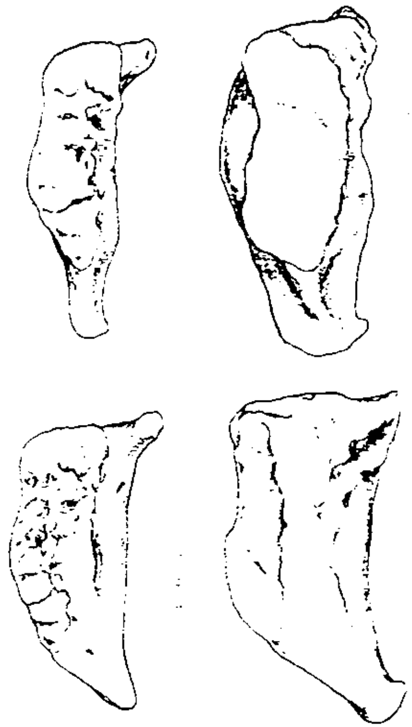


Figure 129. Medial surface of the symphysis pubis of females. Upper right figure emphasizes the flat dorsal demiface surrounded by a complete symphyseal rim. Lower right depicts ventral aspects of rim clearly separating dorsal and ventral demifaces. Left-hand figures depict youthful demifaces not yet completely separated by the ventral aspect of the symphyseal rim (from Gilbert and McKern 1973:Figure 2).

TABLE 33.

Age Distribution of the Stages of Union for Epiphyses of the Anterior Iliac Crest in Females[a]

		Right						Left			
Age	N	Stage of union[b]				Age	N	Stage of union			
11	1	100[c]	-	-	-	11	1	100	-	-	-
14	3	-	67	33	-	14	3	-	-	100	-
15	4	-	75	25	-	15	9	-	44	56	-
16	5	-	-	100	-	16	4	-	-	100	-
17	3	-	-	100	-	17	6	-	-	100	-
18	8	-	-	63	37	18	16	-	-	69	31
19	5	-	-	40	60	19	9	-	-	56	44
20	4	-	-	25	75	20	14	-	-	14	86
21	4	-	-	-	100	21	8	-	-	-	100
22	6	-	-	-	100	22	13	-	-	8	92
23	5	-	-	20	80	23	10	-	-	10	90
24–39	68	-	-	-	100	24–39	105	-	-	-	100
Total	116					Total	198				

[a]Data courtesy of J. Suchey.
[b]Stages of union:
1) non-union without epiphysis.
2) non-union with separate epiphysis.
3) partial union.
4) complete union.
[c]Stage-of-union figures given in percentages.

Sex Estimation

As in the living, the best area to determine the sex of a skeleton is the pelvis. The highest accuracy has been achieved using this bone (see Genovés 1959; Krogman 1962; Phenice 1969; Washburn 1948).

By the time an individual has reached the level of academic achievement that he is able to read this manual, he already has observed that the fen ale has a broader pelvis (hips) than the male. This can be observed es; ially during the spring and summer when coats have been replaced by :ore tight-fitting apparel. This greater width is due to changes th: ughout the female pelvis. These differences are summarized and expanded below.

Pubic Bone (Figure 131)

Females have a longer pubic portion of the hip bone (Figure 128a). Therefore, the subpubic angle is greater in females (Figure 128b). As a

"rule of thumb," when the index finger is held perpendicular to the pubic symphysis the thumb can be moved only slightly, if at all, on a male innominate, but has ample room for movement on a female innominate (Figure 128c).

Attachment of the Arcuate Ligament

There are three characteristic areas of the female pubis and ischiopubic ramus that serve to distinguish the sexes in over 95% of cases (Phenice

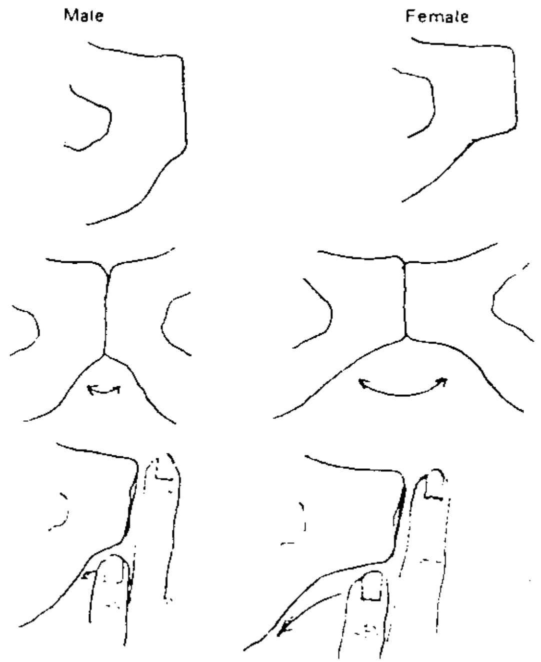


Figure 131. Sexing the pelvis using three general rules: a, pubic portion; b, subpubic angle; c, subpubic concavity.

1969): the ventral arc, the subpubic concavity, and the medial aspect of the ischiopubic ramus.

The ventral arc is a slightly elevated ridge of bone that takes a course across the ~~ventral~~ surface of the female pubis (Figure 132a).

The subpubic concavity is a lateral curvature a short distance inferior to the ~~symphysis in the~~ female. This is best observed from the dorsal surface of the bone (Figure 132b).

In the female, the medial aspect of the ischiopubic ramus presents a

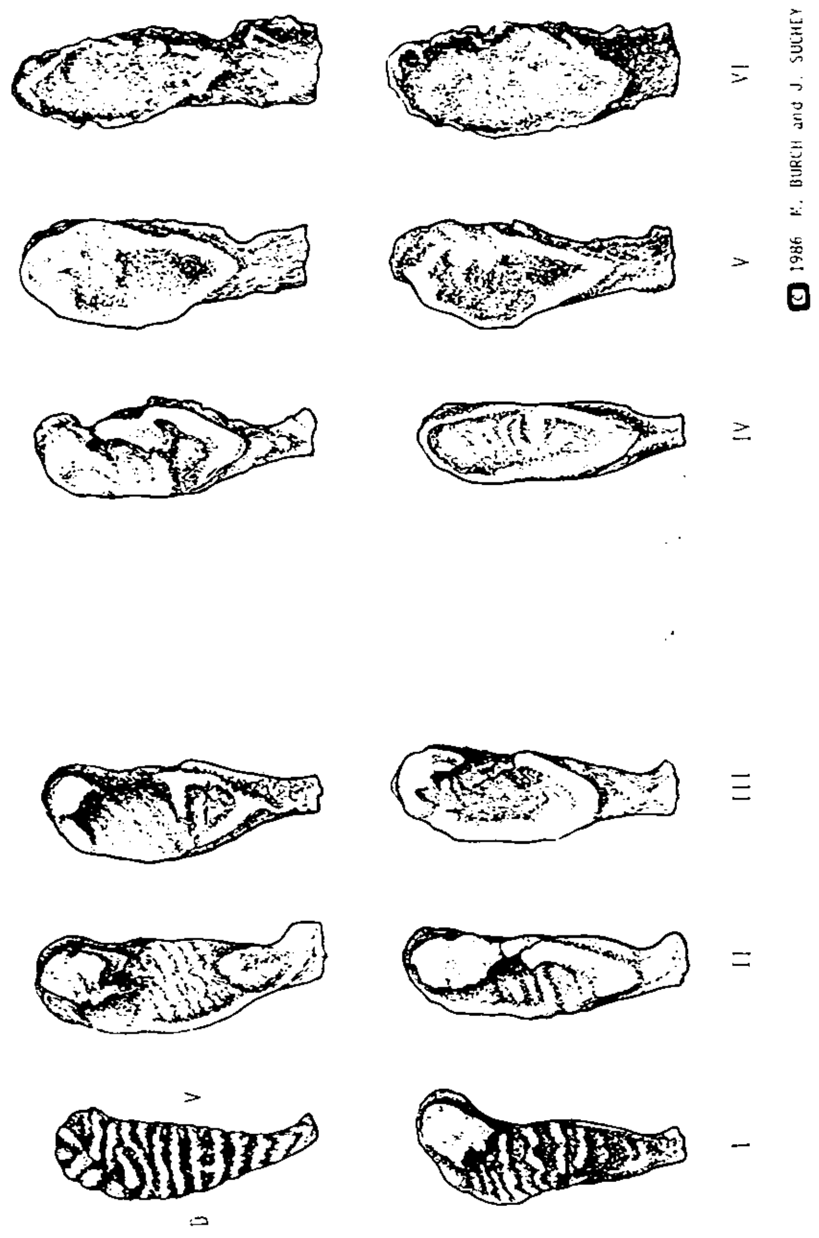


Figure 130. Suchey–Brooks Male Pubic Symphyseal Phases (I–VI), based on Katz and Suchey 1986:427–35. Left side illustrated: D = dorsal, V = ventral. Permission for reproduction granted by J. Suchey.

TABLE 31.

General Rules for Skeletal Age Estimation Using Epiphyseal Union of the Anterior Iliac Crest[a]

Stages of union	Males	Females
Non-union with or without separate epiphysis present	19 years or less	15 years or less
Partial union	14–23 years	14–23 years
Complete union	17 years or more	18 years or more

[a]Data courtesy of J. Suchey.

TABLE 32.

Age Distribution of the Stages of Union for Epiphyses of the Anterior Iliac Crest in Males[a]

Right: Age	N	Stage of union[b] 1	2	3	4	Left: Age	N	Stage of union 1	2	3	4
11	2	100[c]	-	-	-	11	2	100	-	-	-
13	3	67	33	-	-	13	3	67	33	-	-
14	4	50	50	-	-	14	7	43	43	14	-
15	9	11	78	11	-	15	12	25	67	8	-
16	17	6	29	65	-	16	24	4	33	63	-
17	10	-	20	70	10	17	22	-	9	82	9
18	11	-	9	55	36	18	30	-	7	53	40
19	17	-	12	29	59	19	34	-	9	47	44
20	14	-	-	21	79	20	28	-	-	25	75
21	13	-	-	15	85	21	29	-	-	10	90
22	20	-	-	-	100	22	38	-	-	-	100
23	14	-	-	7	93	23	30	-	-	3	97
24–40	185	-	-	-	100	24–40	263	-	-	-	100
Total	319					Total	522				

[a]Data courtesy of J. Suchey.
[b]Stages of union:
1) non-union without epiphysis.
2) non-union with separate epiphysis.
3) partial union.
4) complete union.
[c]Stage-of-union figures given in percentages.

ridge or a narrow surface immediately below the symphyseal surface (Figure 132c).

In the male, there is no ventral arc. A ridge may appear on the ventral surface and take one of the two forms shown in Figure 132. A ridge on the male pubis rarely if ever appears as the ventral arc of the female. This is particularly true if the pubis is oriented for proper observation, with the ventral surface directly facing the observer and the symphyseal surface in a direct anterior–posterior plane (Figure 133a). In addition, in the male there rarely is a subpubic concavity. Finally, the medial aspect of the ischiopubic ramus in males is a broad surface (Figure 133b). When one or two of these three criteria are ambiguous, there almost always will be one that is definitely male or female. In such cases, sex estimation should be based on the most distinctive criterion in the particular specimen (Figure 134). The presence or absence of the ventral arc probably carries the most weight of the ~~three criteria~~.

The sciatic notch is wide in females and narrow in males. Another "rule of thumb" is to place your thumb in ~~the sciatic notch~~. If the notch is filled or there is only limited side-to-side movement possible, it is a male. If considerable side-to-side movement is possible, it is a female (Figure 135a).

In many innominate bones the areas of the sacroiliac articulation is raised in females

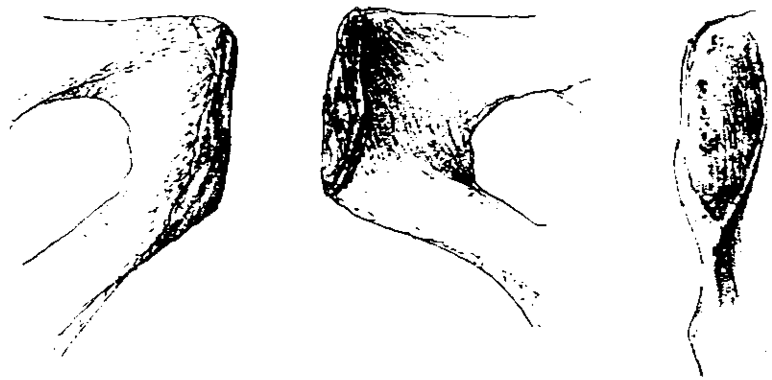
The preauricular sulcus is a depression between the sciatic notch and the sacroiliac articulation. It most often is found in females (Figure 135c).

Iscan and Derrick (1984) note that the postauricular space is most reliable in visually determining sex from this area. The postauricular space is created by the raised sacroiliac articulation found in females but not in males.

Starting in the nonarticular area posterior to the sacroiliac articulation (postauricular sulcus) in a male, you normally can draw your pencil across the sacroiliac articulation of the ilium. This portion of the ilium where it articulates with the sacrum is flat in males. There is a build up in this same area in a female so that beginning in the postauricular sulcus the pencil encounters a ridge of bone in the sacroiliac-articular area.

There are additional morphological observations that help in sex estimation, but generally they are felt to be of minor value (Figure 136). Several of the more useful observations are listed below:

1. In general the male pelvis is more robust and muscle marked.
2. The obturator foramen is larger and oval shaped in males, whereas it is smaller and more triangular in females.
3. Since the female pelvis is adapted for childbirth, the pelvic basin is more spacious and less funnel shaped (see Figure 136).
4. The acetabulum is larger in males to accomodate the larger femoral head.



a b c

Figure 132. Female pelvis: a, ventral arc; b, subpubic concavity (dorsal surface); c, narrow medial aspect of the ischiopubic ramus.

a b

Figure 133. Male pelvis: a, left ventral view (no ventral arc); b, broad medial aspect of the ischiopubic ramus.

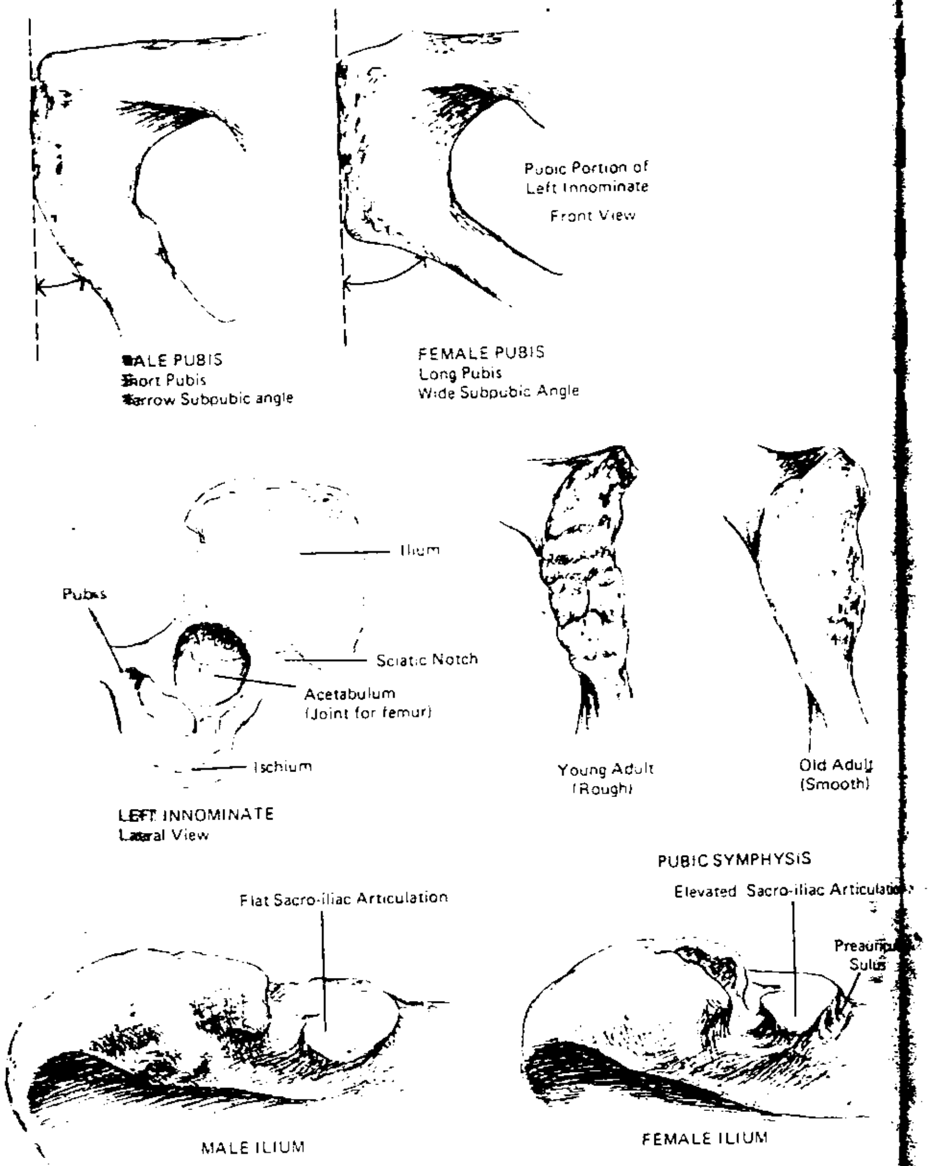


Figure 134. Distinctive criteria useful for aging and sexing the pelvis.

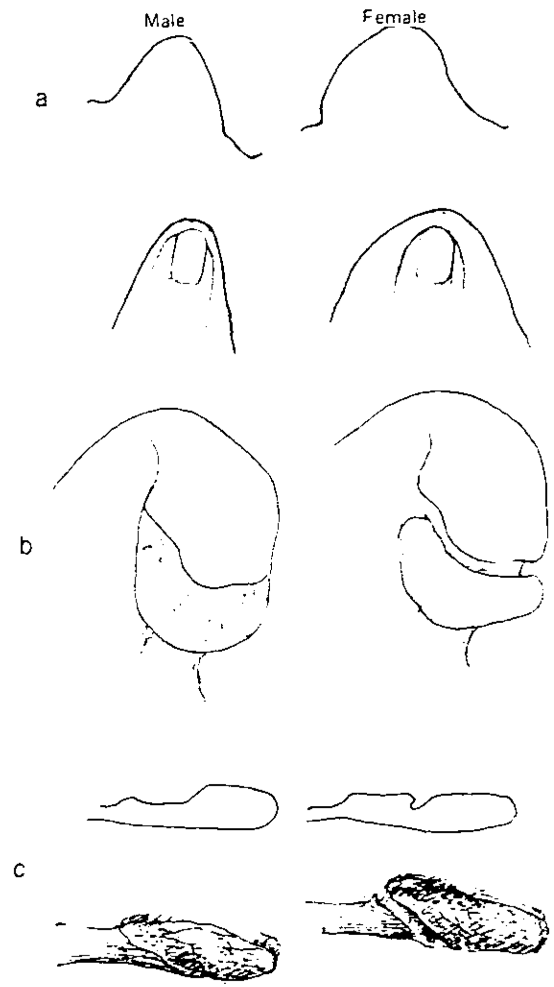
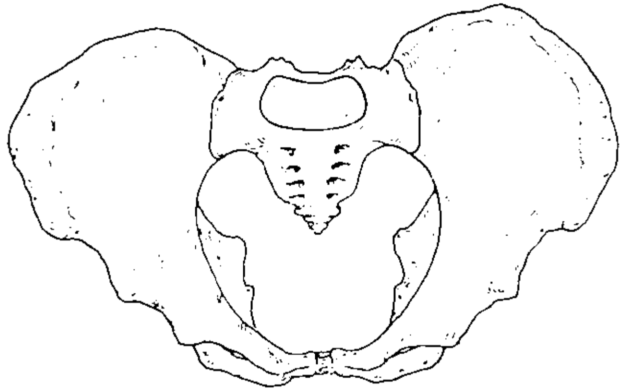


Figure 135. Additional characteristics useful for sexing the pelvis: a, sciatic notch; b, sacroiliac joint; c, preauricular sulcus.



Male pelvis

Female pelvis

Figure 136. Morphological differences between the male and female pelves.

Femur: Paired Long Bone (figures 137–139)

Subadult Bone

The femur is ossified from a primary center for the shaft, which appears about the eighth week of intrauterine life, and from four epiphyseal centers (Figure 138).

The distal epiphysis begins to ossify before birth (this usually is the only secondary center to appear before birth). The nucleus for the head appears at about one year. Those for the greater trochanter appear about the fourth year and for the lesser trochanter about the eleventh year (Figure 139).

The epiphyses at the proximal (head) end of the femur unite before those at the distal end. The epiphyses for the head and the greater and lesser trochanter unite between ages 14 and 19. McKern and Stewart (1957:48) found that 80% of their young-male samples were united by 18. In females, the distal epiphysis unites from 14 (females) to 18 (Pyle and Hoerr 1955). McKern and Stewart (1957:48) further note that for their male sample, "ossification is still in early stages as late as 20 years and does not become complete for all cases until the 22nd year."

Adult Bone

The femur is the largest and longest bone in the skeleton and articulates with the hip bone superiorly and with the tibia inferiorly (at the knee). The heads of the two femora are widely separated by the pelvis, but the femur in erect posture inclines from above down, slightly backwards, and medially so that the distal ends are fairly close together at the knee. The superior extremity, the head, is smooth for articulation and forms two-thirds of a sphere to allow for greater mobility at the hip joint.

The linea aspera, a longitudinally projecting ridge on the posterior surface, is for attachment of muscles used for upright stature and is found only in man.

Bones of Similar Shape where Confusion May Arise

It is possible for a student with little experience to confuse the shafts of the humerus and tibia with the femur, but minimal practice with any of the three soon solves this problem. The femur, as the largest bone of the body, has a larger shaft than the humerus and has a linea aspera. No comparable line is found on the shaft of the humerus. The shaft of the femur is smooth and rounded, whereas the shaft of the tibia is triangular.

FEMUR

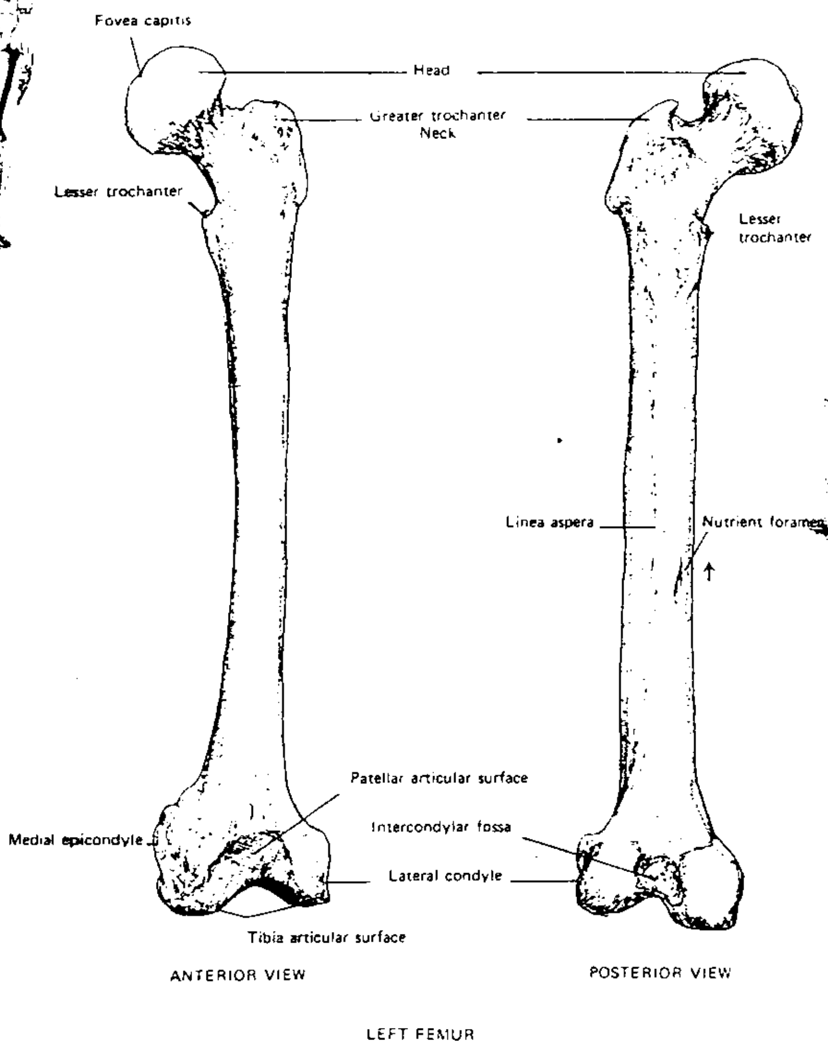


Figure 137. Characteristic features of the femur (left bone depicted).

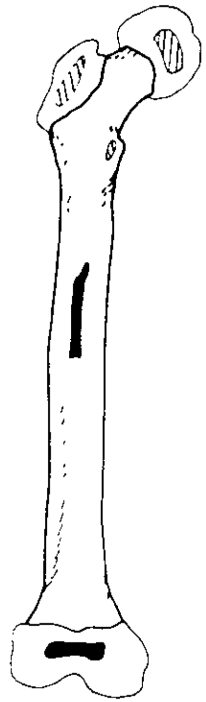


Figure 138. Typical ossification of the femur.

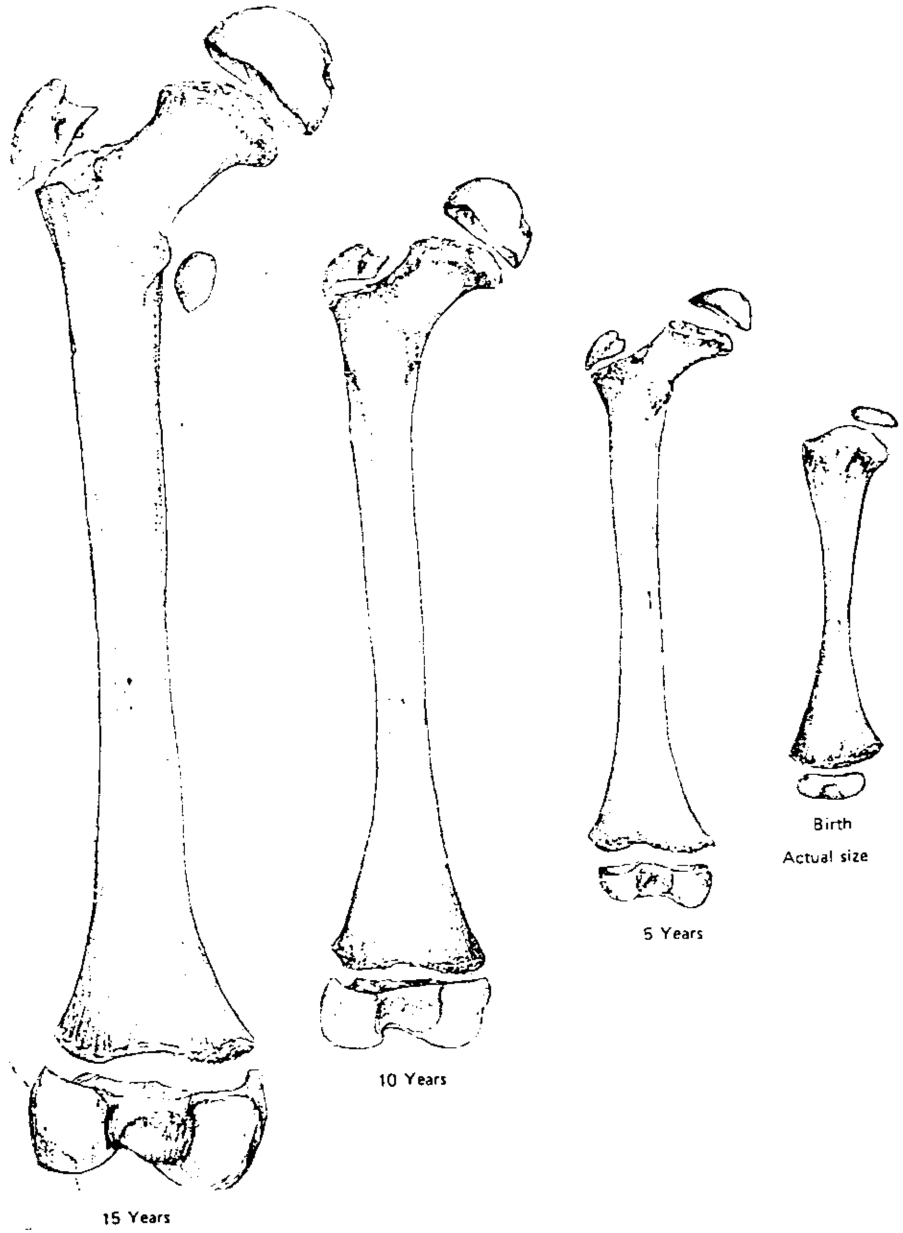


Figure 139. Developmental stages of the femur at birth and at 5, 10, and 15 years.

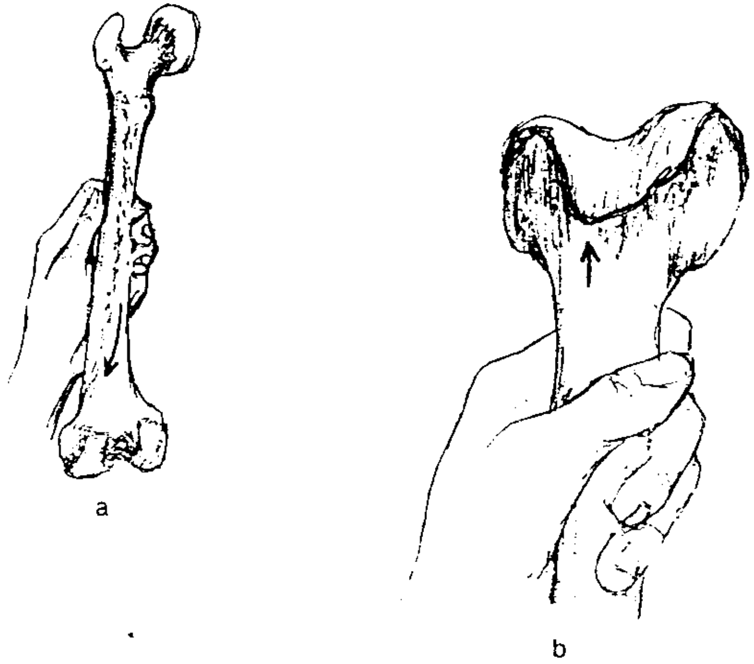


Figure 140. Methods used to distinguish right from left femur (left femur illustrated): a, positions 1 and 2; b, position 3.

Side Identification

When holding the bone in approximate anatomical position, the head of the femur is superior and is opposite the side the bone is from (on the medial side) (Figure 140a).

If you have only the shaft, locate the nutrient foramen and note that it is inclined proximally (toward the head) and is on the posterior surface of the shaft. Holding the posterior surface of the shaft toward you and the proximal end away from you, the linea aspera descends the bone and is inclined off to the side the bone is from (Figure 140a).

If you have only the distal end, hold the anterior surface toward you; the intercondylar fossa will be away from you. The patellar articular surface comes farther up the shaft (toward your hand) on the same side the bone is from (Figure 140b).

Note that the head of the femur has a pit in the articular surface, called the fovea capitis. Compare this with the head of the humerus, which has no fovea. This is an excellent way of determining from a fragmentary head whether it is a humerus or a femur (Figure 141).

Figure 141. Morphological differences between the proximal ends of the femur and humerus.

Measurements of the Femur (Figure 142)

The femur is one of the most measured and reported bones of the body. ..alls (1924) lists 35 measurements for the femur. The following are basic ..asurements only.

1. Maximum length (osteometric board). Place the distal condyles against the fixed vertical of the board and the movable upright to the head. Raise the bone slightly and move it up and down as well as from side to side until maximum length is obtained (A–B).
2. Bicondylar (oblique or physiological) length (osteometric board). Place both condyles against the fixed upright of the board, and with the bone lying on the board apply the movable end to the head (C–D).
3. Anterior–posterior diameter of the midshaft (sliding caliper). Locate midpoint of the shaft on the osteometric board and mark the bone with a pencil. Measure maximum anterior–posterior diameter (S–T).
4. Mediolateral diameter of the midshaft (sliding caliper). Measurement taken at right angles to the anterior–posterior diameter of the midshaft. The linea aspera should be midway between the two branches of the caliper (M–N).

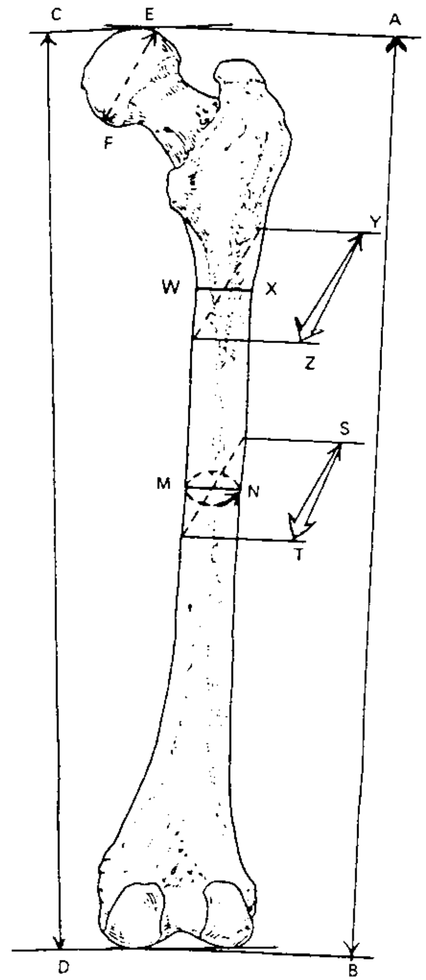


Figure 142. Landmarks for measuring the femur.

5. Maximum diameter of the head (sliding caliper). Measured on the periphery of the articular surface of the head. Rotate the bone until the maximum distance is obtained (E–F).
6. Circumference of the midshaft (tape). Taken at the middle of the shaft. The cloth tape should be made to follow the contours of the bone even when the linea aspera is prominent.
7. Subtrochanteric anterior–posterior diameter (sliding caliper). Taken on the shaft just below the lesser trochanter, avoiding the gluteal tuber-

osity, this measurement gives the minimum diameter of flattening (Y–Z).

8. Subtrochanteric mediolateral diameter (sliding caliper). Taken at the same level as the previous measurement but perpendicular to it; this gives the maximum lateral diameter of flattening (W–X).
9. Platymeric Index: The proximal part of the shaft of the femur shows considerable difference in general shape among various populations.

$$\text{Platymeric Index} = \frac{\text{subtrochanteric anterior–posterior diameter} \times 100}{\text{subtrochanteric mediolateral diameter}}$$

Range:
Platymeric—X–84.9—broad or flat (from front to back)
Eurymeric—85.0–99.9
Stenomeric—100.00–X—(usually only found in pathological cases)

Brothwell (1963:Table 2) provides a concise discussion of the possible cause of differences in the Platymeric Index and gives the following degrees of known variability.

Fossil man:	Cro-Magnon man	73*
	Neanderthal man	77
Recent groups:	Turks	73
	American Indians	74
	Andamanese	78
	Eskimo	81
	Australians	82
	English (17th cent.)	85

*From Brothwell (1963:Table 2).

10. Robusticity Index: expresses the relative size of the shaft.

$$\text{Robusticity Index} = \frac{\text{anterior–posterior} + \text{mediolateral diameter of midshaft} \times 100}{\text{bicondylar (physiological) length}}$$

Age Estimation

Fetal—The femur is one of the few bones of the skeleton on which measurements of maximum length have been reported for the fetal skeleton.

Often, especially in archaeological material, the diaphysis or shaft is present but the epiphyses are not. When faced with the problem of

estimating the age at death from a diaphysis only (do not include epiphyses), the information presented in figures 143 and 144 (after Stewart 1968) will be helpful.

Additional information on the growth of long bones in infants and children has been gathered from the Indian Knoll skeletal sample by Johnston (1962:249–54). The relation of age to length of the subadult bone is shown in Table 34, where bone length is in mm.

Tables 35 and 36 (after Anderson *et al.* 1964:1197–1202) give femur length for children from ages 1 to 18 taken from roentgenograms. Measurements were made of the entire bone, including both proximal and distal epiphyses. Caution should be used when dealing with archaeological material where one or both epiphyses may be missing and where the cartilaginous growth plate between the epiphysis and diaphysis almost always is missing. Anderson *et al.* (1964:1202) state that measurement of the "femur was recorded as the distance from the proximal articulating surface of the capital epiphysis to the most distal point on the lateral condyle." Bone lengths are in cm.

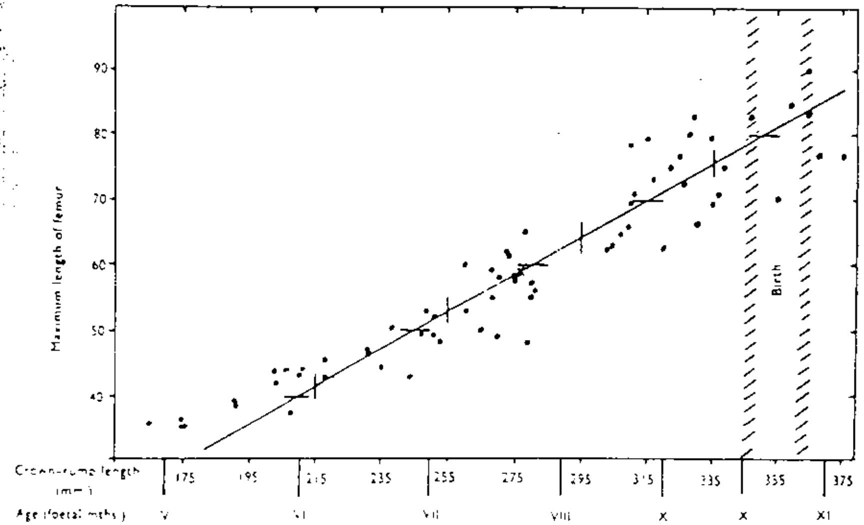


Figure 143. Distribution of maximum dried femur lengths in 65 fetal skeletons, plotted against crown-rump length as obtained in the same specimens before maceration. The ages in fetal months corresponding to the crown-rump lengths (Scammon 1937) also are charted. By locating on the regression line the length of any femur belonging in this size range, the approximate age may be found by noting the corresponding value on the horizontal axis (from Stewart 1968:Figure 53).

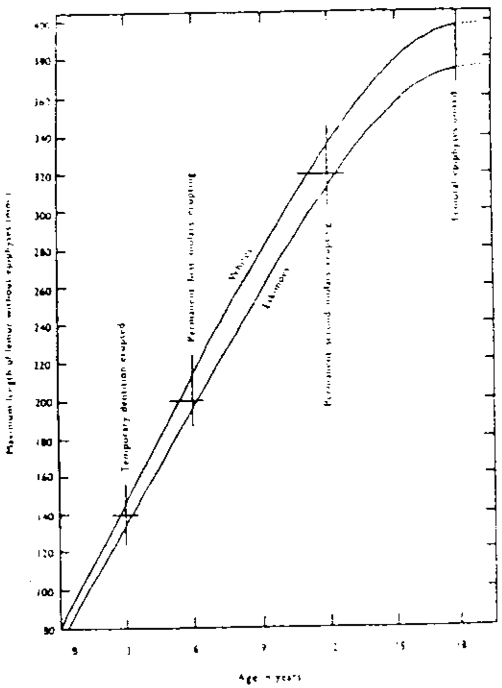


Figure 144. Generalized postnatal growth curve of the femur (length of dried bone without epiphyses) based on a series of Eskimo examples, the ages of which were estimated from the teeth. The accompanying generalized curve for whites takes into account the known differences in size at maturity. The approximate age of a femur belonging in this size range can be determined by locating its length on the appropriate curve and noting the age listed directly below (from Stewart 1968: Figure 54). Permission for reproduction granted by T. D. Stewart and John Wright and Sons, Ltd., Bristol.

TABLE 34.

Age Estimation from Femur[a]

Estimated age in years	Femur N	Mean[b]	Standard deviation
Fetal	7	61.86	6.33
NB–0.5	64	78.84	7.23
0.5–1.5	38	115.63	18.34
1.5–2.5	8	148.13	10.76
2.5–3.5	11	166.73	9.99
3.5–4.5	11	183.82	9.20
4.5–5.5	6	213.67	4.52

[a]After Johnston (1962:Table 2).
[b]All measurements in mm.

TABLE 35.

Lengths of the Femur (Male Children)[a] Including Epiphyses from Orthoroentgenographic Measurements[b]

N	Age	Mean	SD^c_d	SD_m	Distribution $+2SD_d$	$+1SD_d$	$-1SD_d$	$-2SD_d$
21	1	14.48	0.628	0.077	15.74	15.11	13.85	13.22
57	2	18.15	0.874	0.107	19.90	19.02	17.28	16.40
65	3	21.09	1.031	0.126	23.15	22.12	20.06	19.03
66	4	23.65	1.197	0.146	26.04	24.85	22.45	21.26
66	5	25.92	1.342	0.164	28.60	27.26	24.58	23.24
67	6	28.09	1.506	0.184	31.10	29.60	26.58	25.08
67	7	30.25	1.682	0.205	33.61	31.93	28.57	26.89
67	8	32.28	1.807	0.221	35.89	34.09	30.47	28.67
67	9	34.36	1.933	0.236	38.23	36.29	32.43	30.49
67	10	36.29	2.057	0.251	40.40	38.35	34.23	32.18
67	11	38.16	2.237	0.276	42.63	40.40	35.92	33.69
67	12	40.12	2.447	0.299	45.01	42.57	37.67	35.23
67	13	42.17	2.765	0.338	47.70	44.95	39.40	36.64
67	14	44.18	2.809	0.343	49.80	46.99	41.37	38.56
67	15	45.69	2.512	0.307	50.71	48.20	43.19	40.67
67	16	46.66	2.244	0.274	51.15	48.90	44.42	42.17
67	17	47.07	2.051	0.251	51.17	49.12	45.02	42.97
67	18	47.23	1.958	0.239	51.15	49.19	45.27	43.31

[a]Longitudinal series of 67 children.
[b]After Anderson *et al.* (1964:Table 1).
[c]Refers to standard deviation.

TABLE 36.

Lengths of the Femur (Female Children)[a] Including Epiphyses from Orthoroentgenographic Measurements[b]

N	Age	Mean	SD^c_d	SD_m	Distribution			
					$+2SD_d$	$+1SD_d$	$-1SD_d$	$-2SD_d$
30	1	14.81	0.673	0.082	16.16	15.48	14.14	13.46
52	2	18.23	0.888	0.109	20.01	19.12	17.34	16.45
63	3	21.29	1.100	0.134	23.49	22.39	20.19	19.09
66	4	23.92	1.339	0.164	26.60	25.26	22.58	21.24
66	5	26.32	1.437	0.176	29.19	27.76	24.88	23.45
66	6	28.52	1.616	0.197	31.75	30.14	26.90	25.29
67	7	30.60	1.827	0.223	34.25	32.43	28.77	26.95
67	8	32.72	1.936	0.236	36.59	34.66	30.78	28.85
67	9	34.71	2.117	0.259	38.94	36.83	32.59	30.48
67	10	36.72	2.300	0.281	41.32	39.02	34.42	32.12
67	11	38.81	2.468	0.302	43.75	41.28	36.34	33.87
67	12	40.74	2.507	0.306	45.75	43.25	38.23	35.73
67	13	42.31	2.428	0.310	47.17	44.74	39.88	37.45
67	14	43.14	2.269	0.277	47.68	45.41	40.87	38.60
67	15	43.47	2.197	0.277	47.86	45.67	41.27	39.08
67	16	43.58	2.193	0.268	47.97	45.77	41.39	39.19
67	17	43.60	2.192	0.268	47.98	45.79	41.41	39.22
67	18	43.63	2.195	0.269	48.02	45.82	41.44	39.24

[a]Longitudinal series of 67 children.
[b]After Anderson *et al.* (1964:Table 2).
[c]Refers to standard deviation.

Sex Estimation

As stated earlier, the femur is one of the most studied bones of the skeleton and as such has contributed a great deal to the literature on sex estimation. The following data on the diameter of the femoral head originally were suggested by Pearson (1917-1919:56) (Table 37), but see also Krogman (1962:144). It should be cautioned that Pearson's measurement were taken on seventeenth-century bones from London and that most modern populations are larger (Figure 145).

In discussing sex estimation of the Negro skeleton, Thieme (1957) gives the following data for femur length and femur-head diameter (Table 38).

A technique for assessing the sex of fragmentary femora has been suggested by Black (1978). Using femoral midshaft circumference from 114 individuals from the Libben site in Ohio, Black was able to arrive at the same sex determination in 85–90% of the cases as when all sexing criteria were used. He measured the femoral circumference at midshaft to the

TABLE 37.

Rules for Sexing the Femur[a]

	Female	Female?	Sex?	Male?	Male
Vertical diameter	<41.5[b]	41.5–43.5	43.5–44.5	44.5–45.5	>45.5
Popliteal length	<106	106–114.5	114.5–132	132–145	>145
Bicondylar width	<72	72–74	74–76	76–78	>78
Trochanteric oblique length	<390	390–405	405–430	430–450	>450

[a]After Pearson (1917–1919:Table 27).
[b]All measurements in mm.

nearest mm with a cloth tape made to follow the contour of the bone, even on femora with prominent linea aspera. Black (1978:229) states that:

Femoral circumference greater than 81 mm = males
Femoral circumference less than 81 mm = females

Black (1978:230) cautions that "a new function should be calculated for each population to be considered."

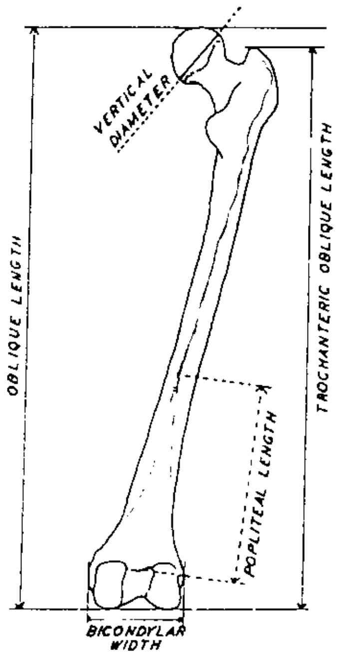


Figure 145. Pearson's femur-measurement system. Diagram of right femur as seen from behind showing measurements referred to in the text (after Pearson 1917-1919: plates 1 and 2).

TABLE 38.

Femur Length and Head Diameter[a]

Measurement	Sex	N	Mean[b]	Standard deviation	Standard error of mean	Critical ratio (t)
Femur length	M	98	477.34	28.37	2.866	10.13
	F	100	439.10	24.55	2.456	10.13
Femur head diameter	M	98	47.17	2.75	0.278	16.17
	F	100	41.52	2.12	0.212	16.17

[a]After Thieme (1957:Table 1).
[b]Measurements in mm.

Di Bennardo and Taylor (1979) tested Black's midshaft femoral circumference on 115 North American white femora of verified age and sex. They found that the midshaft femoral circumference measurement proved as accurate as any other femoral measurement in sexing the femur and that this measurement can be used on other than archaeological populations. Spruiell (1984) applied Black's circumference measurement to a Plains skeletal collection (24 females and 36 males) and achieved a 90.0% level of accuracy in sexing the skeleton when compared with sexing using data on the pelvis.

After measuring the greatest diameter of the femoral head in a series of specimens from the Terry Collection, Stewart (1979:120) states "I feel reasonably safe in recommending the following adjustment in Pearson's and Bell's range subdivision for use in sexing the dry bones of American Whites":

Female	Female?	Sex indeterminate	Male?	Male
<42.5	42.5–43.5	43.5–46.5	46.5–47.5	>47.5

Dittrick (1979) and Dittrick and Suchey (n.d.) have reported on sexual dimorphism of both the femur and humerus from prehistoric central California skeletal samples. Dittrick and Suchey (n.d.) state:

> Nine measurements were taken on both the femora (n = 358) and on the humeri (n = 335). Using discriminate function analysis, the most accurate function was found to utilize three measurements on the femur (maximum diameter of the head, anterior–posterior mid-shaft width, and mid-shaft circumference) and one on the humerus (transverse diameter of the head). This function operates with 96% accuracy on the Early Horizon sample; with 91% accuracy on combined Middle and Late Horizons, and with 91% accuracy when all Horizons are combined. The best single indicator for the femur is the maximum diameter of the head; this function operates with 85% accuracy in the Early Horizon; with 90% accuracy on combined Middle and Late Horizons, and 90% accuracy when all Horizons are combined.

Their measurements and discriminate functions are presented in Table 39.

TABLE 39.

Discriminate Function Sexing by Femur and Humerus Using Prehistoric Samples from Central California (N = 258)[a]

Measurements	Early Horizon	Middle and Late Horizon	Combined Horizon
Femur			
Max. diam. head	−0.07467	+0.14244	+.11533
Midshaft ant. – post.	+0.01620	−0.13878	−.10019
Midshaft circum.	+0.07048	+0.04991	+.04908
Humerus			
Trans. diam. head	+0.28420	+0.14403	+.15762
Male mean	15.7[b]	13.5	13.8
Sectioning point	15.1	12.7	13.1
Female mean	13.9	11.9	12.2
Percent accuracy	96%	91%	91%

[a]After Dittrick (1979:66).
[b]Measurements in cm.

Stature Estimation

The estimation of stature from long bones has been attempted by numerous authors. Only those formulae given by Trotter and Gleser (1952, 1958) will be given (Table 40).

Stature Formulae for the Femur (Male)

White	2.32 femur + 65.53 ± 3.94
Negro	2.10 femur + 72.22 ± 3.91
Mongoloid	2.15 femur + 72.57 ± 3.80
Mexican	2.44 femur + 58.67 ± 2.99

Example

Given a femur (white male) that measures 45.0 cm (450 mm):

2.32 (45.0) + 65.53 ± 3.94

104.40 + 65.53 ± 3.94

169.93 cm = mean

Range 169.93 − 3.94 = 165.09 cm (low)

169.93 + 3.94 = 173.87 cm (high)

TABLE 40.

Estimation of Stature[a] from Long Bones[b]

White females		Negro females	
3.36 Hum. + 57.97	± 4.45	3.08 Hum. + 64.67	± 4.25
4.74 Rad. + 54.93	± 4.24	3.67 Rad.[c] + 71.79	± 4.59
4.27 Ulna + 57.76	± 4.30	3.31 Ulna + 75.38	± 4.83
2.47 Fem.[d] + 54.10	± 3.72	2.28 Fem.[d] + 59.76	± 3.41
2.90 Tib.$_m$ + 61.53	± 3.66	2.45 Tib.$_m$ + 72.65	± 3.70
2.93 Fib. + 59.61	± 3.57	2.49 Fib. + 70.90	± 3.80
1.39 (Fem.$_m$ + Tib.$_m$) + 53.20	± 3.55	1.26 (Fem.$_m$ + Tib.$_m$) + 59.72	± 3.28
1.48 Fem.$_m$ + 1.28 Tib.$_m$ + 53.07	± 3.55	1.53 Fem.$_m$ + 0.96 Tib.$_m$ − 58.54	± 3.23
1.35 Hum. + 1.95 Tib.$_m$ + 52.77	± 3.67	1.08 Hum. + 1.79 Tib.$_m$ + 62.80	± 3.58
0.68 Hum. + 1.17 Fem.$_m$ + 1.15 Tib.$_m$ + 50.12	± 3.51	0.44 Hum. − 0.20 Rad. + 1.46 Fem.$_m$ + 0.86 Tib.$_m$ + 56.33	± 3.22

[a]To estimate stature of older individuals subtract .06 (age in years – 30) cm.
[b]After Trotter and Gleser (1952:Table 18).
[c]From Trotter and Gleser (1977:355).
[d]Mean length of long bone.

Race Estimation

Stewart (1962:50–53) has studied anterior femoral curvature for its utility in race identification. Table 41 is reproduced from his data. Because the measurements used are not standard anthropometric measurements, parts of his section on methods of measurement are reproduced below.

> A simple procedure was used to obtain the few measurements desired initially. Each femur was placed horizontally on a smooth table top so that it rested firmly on the posterior surfaces of the condyles at the distal end and of the greater trochanter (or perhaps better, the quadratus tubercle of the intertrochanteric ridge) at the proximal end. A wooden wedge was then inserted under the quadratus tubercle so as to raise the deepest point (bottom) of the anterior concavity at the proximal end of the shaft to the

TABLE 41.

Race Estimation Using the Femora[a]

Measurement or index[b]	Racial group	Mean	Standard deviation	Range
1. Greater trochanter—lateral condyle length	Negro	450.6	24.1	411–500
	White	426.2	20.2	383–474
	Indian	433.3	18.9	404–482
2. Height of leveling points	Negro	61.3	2.9	55–67
	White	61.7	3.0	55–68
	Indian	64.4	2.6	59–72
3. Height of leveling points relative to length	Negro	13.6	0.7	11.9–14.6
	White	14.5	0.8	13.3–16.4
	Indian	14.9	0.8	13.3–16.4
4. Height of shaft above leveling points	Negro	7.6	2.4	4–15
	White	8.8	2.6	2–15
	Indian	10.9	3.0	6–20
5. Height of shaft relative to length (index of curvature)	Negro	1.7	0.5	0.8–3.3
	White	2.1	0.5	0.5–3.5
	Indian	2.5	0.7	1.3–4.3
6. Distance from greater trochanter to point of maximum curvature	Negro	204.6	28.9	159–287
	White	195.7	17.9	165–238
	Indian	230.3	27.9	185–308
7. Distance to point of maximum curvature relative to length (position index)	Negro	45.3	5.5	35.9–62.1
	White	46.1	3.8	37.0–53.7
	Indian	53.2	6.3	43.4–70.3
8. Indicator of torsion	Negro	15.9	6.4	0–28
	White	15.5	6.4	0–29
	Indian	25.3	5.1	15–39

[a]After Stewart (1962:Table 1).
[b]All measurements in mm.

same level as the bottom of the anterior concavity at the distal end.* The proximal leveling point is located usually toward the medial side of the shaft and, when torsion is minimal, is just above the lesser trochanter, but as torsion increased the point moves distalwards. The distal leveling point is always toward the lateral side of the shaft and 1–2 cm proximal to the anterior margin of the lateral condyle.

Leveling was done by an improvised perigraph consisting of a triangular piece of board with a bisecting groove on the upper surface just large enough to hold firmly the fixed branch of a sliding caliper. In order to measure the height above the table surface of any particular point on the bone, the sliding branch of the caliper was brought into contact with the point, the reading made, and a factor added representing the height of the fixed branch of the caliper above the table surface.

With the bone in the described position, and using the "perigraph" as indicated, the following heights above the table surface were obtained: 1) at the leveling points, 2) at the point of greatest anterior curvature of the diaphysis, 3) at the highest point on the cervicle tubercle (located as shown in figure [146], on the anterior surface of the greater trochanter at the base of the neck), and 4) at the highest point on the head. The difference between heights 1 and 2 gives, of course, a measure of curvature. The last two heights were taken in order to get an indication of the amount of torsion in the proximal part of the bone. In this case, as figure [146] demonstrates, the greater the difference in height between the two points, the greater the torsion. Such a measure of torsion is not commonly used, but seems adequate for the present purpose, and has the advantage of being more easily obtained than the angle of the neck.

In advance of positioning the bone the greatest length between the most proximal point on the greater trochanter and the most distal point on the lateral condyle was obtained with the osteometric board. This measurement was used in ratios with two of the heights. Later, when the bone had been leveled and the point of maximum diaphyseal curvature located, the distance between the proximal extremity of the greater trochanter and the point of greatest anterior curvature of the diaphysis was obtained with a large spreading caliper designed for use in pelvimetry. The ratio of these two length measurements was an important element in the study.

There is more than one way, of course, of measuring the length of the femur. The one used here relates to the shaft proper and ignores the neck and head [See Table 41].

*A descriptive problem is created by the fact that the femur is in the horizontal position. Although this position leads to little, if any, confusion as regards the meaning of the anatomical terms "anterior," "posterior," "lateral," "medial," "proximal," and "distal," it does lead to confusion when common terms of direction are used, such as "upper," "lower," "above," and "below." Once the femur is moved from its standard anatomical position, terms like "proximal" and "upper" or "superior" no longer share a common directional meaning. This explanation may help make my meaning clear when I speak of concavities on the anterior surface of the horizontally placed femur as having deepest points or bottoms; obviously the concavities open upwards (not proximalwards). As another example, the anterior concavity located at the proximal end of the horizontal shaft is often just above (not proximal to) the lesser trochanter.

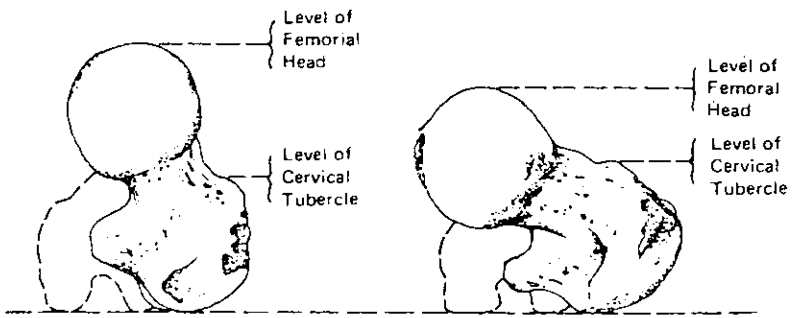


Figure 146. Two femora with very different amounts of torsion viewed from a cranial position when the condyles and intertrochanteric ridges are in alignment. Note that the difference in level between the head and cervical tubercle constitutes an indicator of torsion. The actual figures obtained in these cases (Dakota Indians 325, 354 and 325, 369) were 39 mm and 19 mm, respectively.

Patella (Kneecap): Paired, Irregular Bone (Figure 147)

Subadult bone

The patella may ossify from several centers (Shaeffer 1953). Ossification usually occurs near 38 months (3–4 years) in males and near 29 months (2–3 years) in females (Pyle and Hoerr 1955:51) (Figure 148). The ossification of the patella usually is complete by puberty or shortly thereafter.

Adult Bone

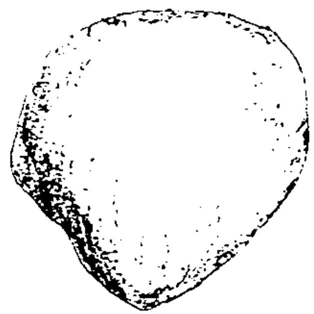
A sesamoid (resembling a grain of sesame) is a flat bone that develops in a tendon that moves over a bony surface. Most sesamoid bones occur in the hands and feet where tendons cross the articulations for the metacarpals, metatarsals, and phalanges, but the largest sesamoid bone in the body is the patella.

The kneecap is triangular in shape with its base proximal and its apex distal. The anterior side is marked by longitudinal striae and is slightly convex and perforated by small openings that transmit nutrient vessels.

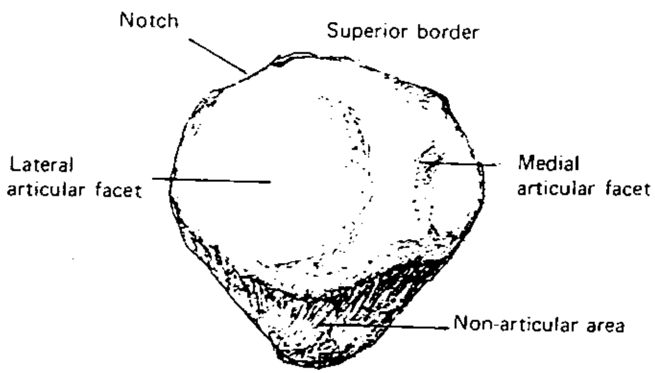
The articular surface is located posteriorly and is divided by a slightly marked longitudinal surface corresponding to the groove on the patellar surface of the femur. The larger lateral portion adapts to the lateral condyle, and the smaller medial portion moves on the medial condyle.

Note that the superior border is thick and the inferior (or nonarticular posterior) border is teardrop in shape or presents a blunt point.

PATELLA (KNEE CAP)



ANTERIOR VIEW



POSTERIOR VIEW

LEFT PATELLA

Figure 147. Characteristic features of the patella (left bone depicted).

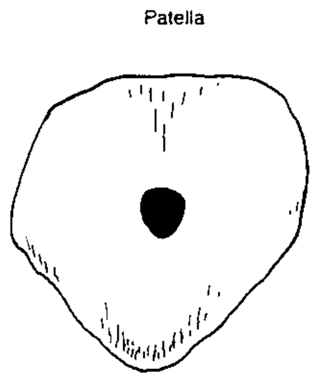


Figure 148. Typical ossification of the patella.

Bones of Similar Shape where Confusion May Arise

None.

Side Identification

Hold the nonarticular, inferior blunt point between your fingers with the articular posterior surface toward you, or by the proximal border and the point as illustrated below. The side with the largest articular surface is on the same side the bone comes from (Figure 149).

On many patellae there is a notch on the superior lateral border. When held as above, this notch is on the same side the bone is from.

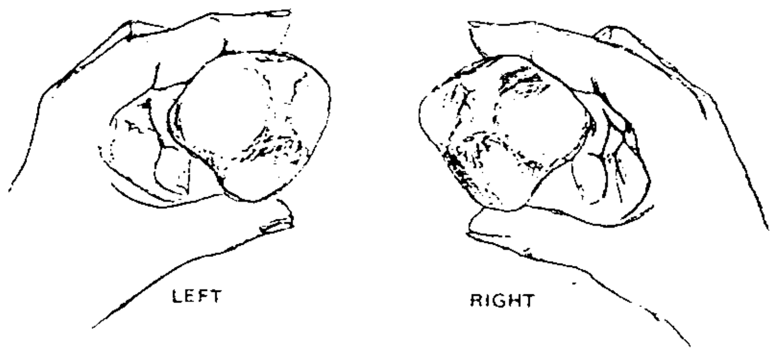


Figure 149. Methods used to distinguish the right from the left patella.

Tibia: Paired Long Bone (Figure 150)

Subadult Bone

The tibia is ossified both from a primary center near the middle of the shaft that appears about the seventh to eighth week of intrauterine life and

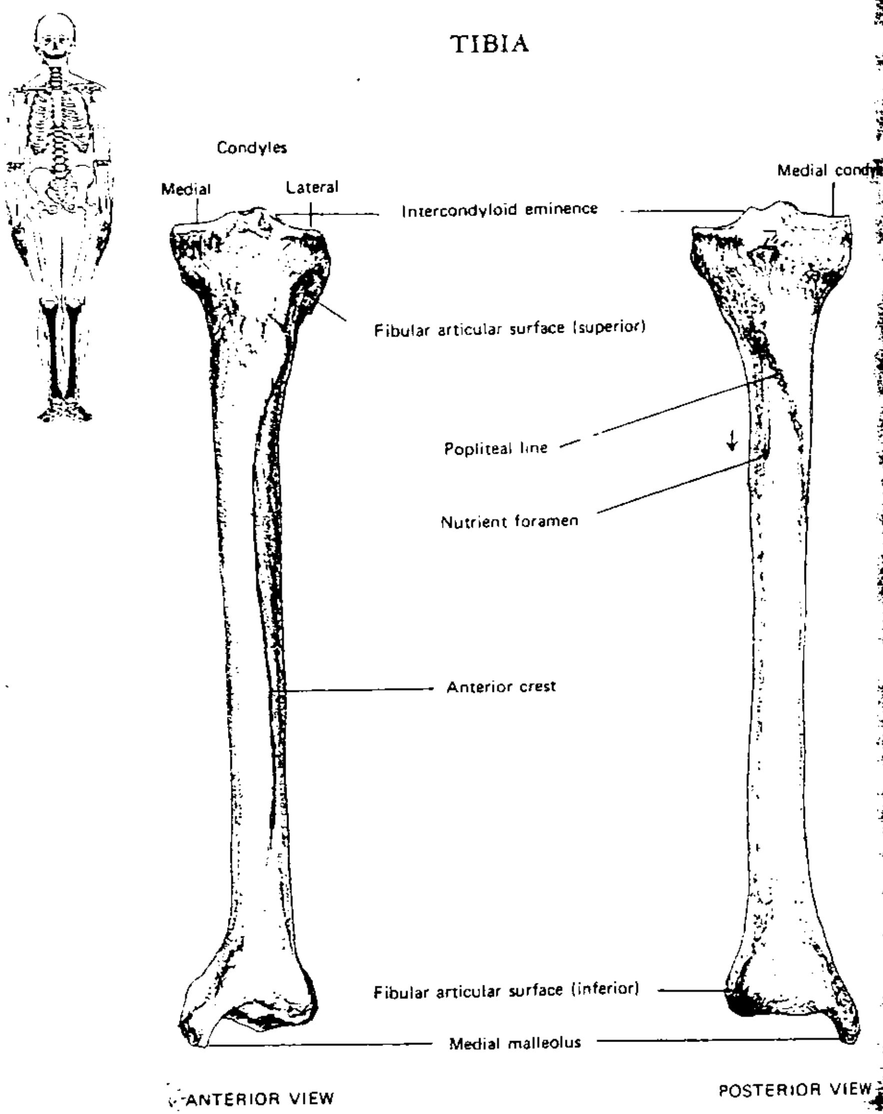


Figure 150. Characteristic features of the tibia (left bone depicted).

from two centers for epiphyses (Figure 151). The epiphysis at the proximal end (knee) appears at birth or slightly before and at the distal end during the first year (Hoerr and Pyle 1962).

The distal epiphysis usually unites to its shaft from age 13 (females) to 18, or some 2 years prior to fusion of the proximal end. McKern and Stewart (1957:49) found complete union for all their American males by age 20.

At the proximal epiphysis, progress for complete union is slower and usually does not occur until the twenty-third year. Pyle and Hoerr (1955:79) state that "the tibial epiphysis is the first epiphysis to fuse with its shaft at the knee," and they find beginning fusion at age 14 in females and between 16 and 17 in males. This again follows the general rule that complete fusion of the epiphyses at hip and ankle occurs at about 18 years of age and at the knee at about 20 (Figure 152).

Adult Bone

The tibia is the largest bone in the lower leg and, after the femur, the second largest bone in the skeleton. The tibia, or shin bone, is situated on the anterior (front) and medial (inside) side of the leg. As with all bones, it is divisible into a superior end, a shaft, and a distal end.

Superior End

This consists of two superior articular surfaces for articulation with the femur. The articular surfaces are separated by the intercondyloid eminence, which is composed of the medial and lateral intercondyloid tubercles.

Just below the lateral femoral articular surface, i.e., on the inferior and lateral aspect of the lateral condyle, is the fibular articular surface, a flat and nearly circular area.

Shaft

The anterior surface of the shaft, containing the anterior crest, is felt easily below the skin of the living for more than half the length of the lower leg. When your fingers reach the crest along the anterior (front) of the leg as you proceed around, or to the outside of, the leg, the bone abruptly drops away.

The posterior surface contains the nutrient foramen and the popliteal line and is slightly concave.

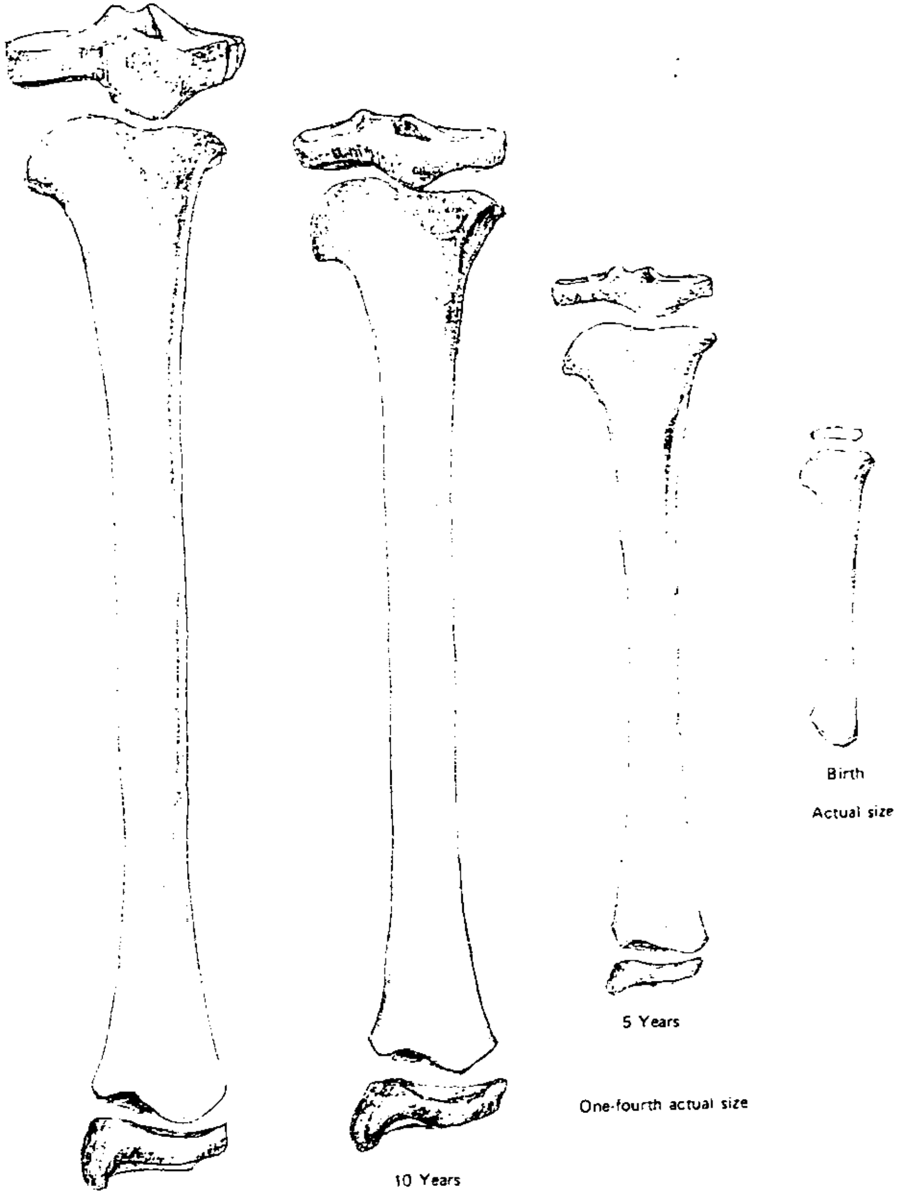


Figure 151. Developmental stages of the tibia at birth and at 5, 10, and 15 years.

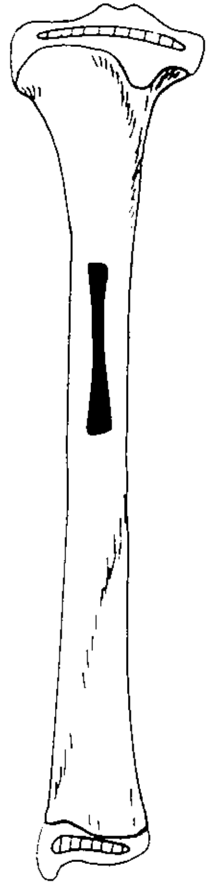


Figure 152. Typical ossification of the tibia.

Distal End

The medial malleolus, which is felt easily on the medial side (inside) of the ankle, is the projection at the distal end.

A concavity occurs on the lateral surface opposite the medial malleolus for the articulation of the fibula. There is no lateral malleolus on the tibia.

Bones of Similar Shape where Confusion May Arise

The shaft of the tibia possibly could be confused with the shaft of the femur. The shaft of the tibia is triangular with sharp, distinct edges,

whereas the shaft of the femur is rounded and smooth. The linea aspera found on the femur does not occur on the tibia. The shaft of the humerus is smaller.

Side Identification

When the bone is held in approximate anatomical position, the fibular articular surfaces are on the same side the bone is from. The medial malleolus therefore is opposite the side the bone comes from (Figure 153a).

Hold the posterior surface toward you with the distal end away from you. You can observe the nutrient foramen (inclined toward the distal end) and the popliteal line. The popliteal line is inclined toward the opposite side the bone comes from.

If you have just the distal end of the tibia, the tip of the medial malleolus always is toward the anterior surface of the bone when viewed from the medial side and will therefore be on the opposite side the bone comes from (Figure 153b).

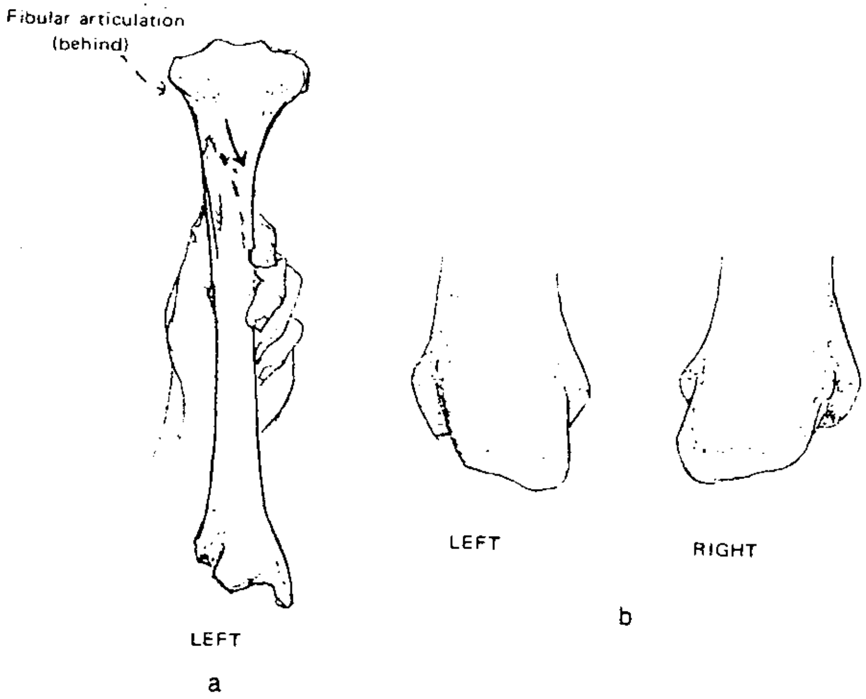


Figure 153. Methods used to distinguish left and right tibia using positions 1 (a) and 3 (b) as described in the text.

If you only have the shaft, locate the nutrient foramen and note that it is inclined distally and is on the posterior surface. Turn the bone over to the anterior surface and note that the sharp anterior crest abruptly drops away on the side the bone is from.

Measurements of the Tibia (Figure 154).

There are various slightly different methods for measuring the length of the tibia. Since this measurement is used predominantly to calculate stature, the techniques employed by Trotter and Gleser (1952:473) are presented below.

1. Maximum length (osteometric board). Place the end of the malleolus against the vertical (fixed) wall of the osteometric board, with the bone resting on its dorsal surface with its long axis parallel to the long axis of the board. Apply the block to the most prominent part of the lateral half of the lateral condyle (A–B).
2. Anterior–posterior diameter at the nutrient foramen (sliding caliper). Take the maximum anterior–posterior diameter of the shaft at the level of the nutrient foramen (at about the proximal one-third) (S–T).
3. Mediolateral diameter at the nutrient foramen (sliding caliper). Maximum transverse diameter at the level of the nutrient foramen (at right angles to the previous measurement) (M–N).
4. Circumference at the nutrient foramen (cloth tape or dental floss). Maximum circumference is taken with a plastic-covered tape. The tape should follow the contour of the bone. (Dental floss can be used and the length measured with a sliding caliper.)
5. Platycnemic Index: expresses the degree of mediolateral flatness of a tibia, from two dimensions taken at the level of the nutrient foramen.

$$\text{Platycnemic Index} = \frac{\text{mediolateral nutrient diameter} \times 100}{\text{anteroposterior nutrient diameter}}$$

Range:
- Hyperplatycnemic—X–54.9
- Platycnemic—55.0–62.9
- Mesocnemic—63.0–69.9
- Eurycnemic—70.0–X

Examples falling within these ranges include Neolithic bones from France (61.5–65.4) (Wilder 1920:131–32; see also Brothwell 1963:92).

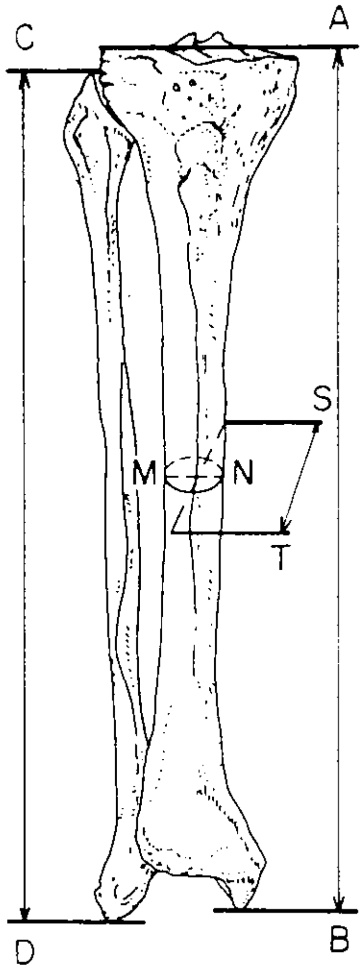


Figure 154. Landmarks for measurements on the tibia and fibula.

Age Estimation

Johnston's (1962) work with skeletal data from Indian Knoll has provided information on the relation of age to length of the subadult tibia, as shown in Table 42 (bone length in mm).

TABLE 42.

Estimation of Age Using Length of the Tibia[a]

Estimated age in years	Tibia N	Mean	Standard deviation
Fetal	6	55.50[b]	7.54
NB–0.5	65	69.28	6.33
0.5–1.5	38	96.87	14.47
1.5–2.5	7	120.57	5.45
2.5–3.5	10	138.20	8.54
3.5–4.5	10	154.30	8.10
4.5–5.5	7	178.43	4.53

[a]After Johnston (1962:Table 2).
[b]All measurements in mm.

The distal epiphysis unites before the proximal.

	Beginning union	Complete union
Distal epiphysis:	11–13 females	17
	14–16 males	20
Proximal epiphysis:	14 females	18
	16–17 males	23

The following tables by Anderson *et al.* (1964) give tibia lengths for children between ages 1 and 18 taken from roentgenograms (tables 43, 44). Measurements were made of the entire bone, including proximal and distal epiphyses. Anderson *et al.* state that measurement of the tibia was recorded as the distance from the midpoint of a line drawn across the proximal condyles to the midpoint of the distal articulating surface. Bone lengths are in cm.

Sex Estimation

The circumference of the shaft of the tibia at the level of the nutrient foramen has been found by Iscan and Miller-Shaivitz (1984a, 1984b) to predict the sex with 77% accuracy for Whites and 80% for Blacks, and the length alone accurate at 66% for Whites and 81% for Blacks. Iscan and Miller-Shaivitz used the four tibiae measurements listed here and based their discriminate function on 159 adult tibiae (40 white males, 39 white females, 40 black males, and 40 black females) from the Terry Collection.

TABLE 43.

Lengths of the Long Bones Including Epiphyses for Sixty-Seven Male Children from Orthoroentgenographic Measurements[a]

Tibia								
					Distribution			
N	Age	Mean[b]	SD^c_d	SD_m	$-2SD_d$	$-1SD_d$	$-1SD_d$	$-2SD_d$
61	1	11.60	0.620	0.074	12.84	12.22	10.98	10.36
67	2	14.54	0.809	0.099	16.16	15.35	13.73	12.92
67	3	16.79	0.935	0.114	18.66	17.72	15.86	14.92
67	4	18.67	1.091	0.133	20.85	19.76	17.58	16.49
67	5	20.46	1.247	0.152	22.95	21.71	19.21	17.97
67	6	22.12	1.418	0.173	24.96	23.54	20.87	19.46
67	7	23.76	1.632	0.199	27.02	25.39	22.13	20.50
67	8	25.38	1.778	0.217	28.94	27.16	23.60	21.82
67	9	26.99	1.961	0.240	30.91	28.95	25.02	23.06
67	10	28.53	2.113	0.258	32.76	30.64	26.42	24.30
67	11	30.10	2.301	0.281	34.70	32.40	27.80	25.50
67	12	31.75	2.536	0.310	36.82	34.29	29.21	26.68
67	13	33.49	2.833	0.346	39.16	36.32	30.66	27.82
67	14	35.18	2.865	0.350	40.91	38.04	32.32	29.45
67	15	36.38	2.616	0.320	41.61	39.00	33.76	31.15
67	16	37.04	2.412	0.295	41.86	39.45	34.63	32.22
67	17	37.22	2.316	0.283	41.85	39.54	34.90	32.59
67	18	37.29	2.254	0.275	41.80	39.54	35.04	32.78

[a]After Anderson *et al.* (1964:Table 2).
[b]All measurements in cm.
[c]Refers to standard deviation.

TABLE 44.

Lengths of the Long Bones Including Epiphyses for Sixty-Seven Female Children from Orthoroentgenographic Measurements[a]

Tibia								
					Distribution			
N	Age	Mean[b]	SD^c_d	SD_m	$+2SD_d$	$-1SD_d$	$-1SD_d$	$-2SD_d$
61	1	11.57	0.646	0.082	12.86	12.22	10.92	10.28
67	2	14.51	0.739	0.090	15.99	15.25	13.77	13.03
67	3	16.81	0.893	0.109	18.60	17.70	15.92	15.02
67	4	18.66	1.144	0.140	21.15	20.00	17.72	16.57
67	5	20.77	1.300	0.159	23.37	22.07	19.47	18.17
67	6	22.53	1.458	0.178	25.45	23.99	21.07	19.61
67	7	24.22	1.640	0.200	27.50	25.86	22.58	20.94
67	8	25.89	1.786	0.218	29.46	27.68	24.10	22.32
67	9	27.56	1.993	0.243	31.55	29.55	25.57	23.57
67	10	29.28	2.193	0.259	33.67	31.47	27.09	24.89
67	11	31.00	2.384	0.291	35.77	33.38	28.62	26.23
67	12	32.61	2.424	0.296	37.46	35.03	30.19	27.76
67	13	33.83	2.374	0.290	38.58	36.20	31.46	29.08
67	14	34.43	2.228	0.272	38.89	36.66	32.20	29.97
67	15	34.59	2.173	0.265	38.94	36.76	32.42	30.24
67	16	34.63	2.151	0.263	38.93	36.78	32.48	30.33
67	17	34.65	2.158	0.264	38.97	36.81	32.49	30.33
67	18	34.65	2.161	0.264	38.97	36.81	32.49	30.33

[a]After Anderson *et al.* (1964:Table 2).
[b]All measurements in cm.
[c]Refers to standard deviation.

Symes and Jantz (1983) have been able to obtain accurate sexing with tibiae using a multivariate discriminate function analysis. They suggest three measurements. The breadth measurements are taken most easily with the the use of an osteometric board, placing the posterior side of the bone down. The circumference measurement is taken with a metal tape pulled tightly around the shaft at the level of the nutrient foramen. Once an accurate measurement is obtained, simply compare that score to the univariate sectioning point, with males falling above and females below (Table 45). Original data for this analysis were obtained from the Terry Collection and a postcontact burial sample of northern Plains Indians (Symes and Jantz 1983).

TABLE 45.

Univariate Discriminant Function Sectioning Points for Whites, Blacks, and Arikara Indian Tibiae[a]

Group	Proximal breadth	%[b]	Distal breadth	%	Circumference at nutrient foramen	%
Whites						
Sectioning point	75.11		49.24		90.16	
Male mean	79.56		52.23		95.97	
Female mean	70.66		46.24		84.34	
		88.75		86.25		82.50
Blacks						
Sectioning point	74.82		48.08		92.76	
Male mean	79.49		51.04		99.80	
Female mean	70.14		45.11		85.72	
		91.36		87.65		86.42
Arikara Indians						
Sectioning point	74.56		50.88		91.21	
Male mean	79.15		54.18		98.58	
Female mean	69.97		47.58		83.84	
		96.15		92.31		92.31

[a]From Symes and Jantz (1983).
[b]Percentage accuracy.
[c]Measurements given in mm.

Stature Estimation

Stature-calculation formulae given by Trotter and Gleser (1952, 1958) are the basis for the following discussion of stature estimation from long bones.

Stature Formulae for the Tibia (Male)

White	2.42 tibia + 81.93 ± 4.00
Negro	2.19 tibia + 85.36 ± 3.96
Mongoloid	2.39 tibia + 81.45 ± 3.27
Mexican	2.36 tibia + 80.62 ± 3.73

Fibula: Paired Long Bone (figures 155–157)

Subadult Bone

The fibula ossifies from a single center appearing about the eighth week of intrauterine life near the center of the shaft (Figure 156). The nucleus of

FIBULA

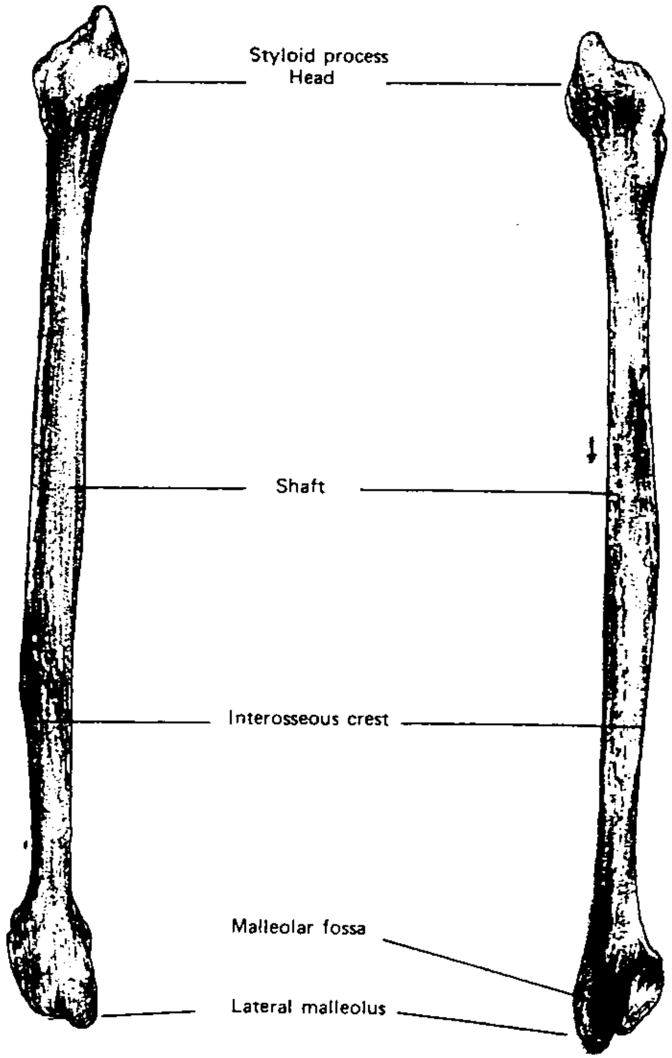


Figure 155. Characteristic features of the fibula (left bone depicted).

Figure 156. Ossification centers of the fibula.

the epiphysis for the distal end appears around age one (Hoerr and Pyle 1962:74). The nucleus for the proximal epiphysis appears at about 3 years in girls and 4 years in boys (Pyle and Hoerr 1955:52).

As is true in the tibia, the distal epiphysis unites earlier that the proximal epiphysis by some 2 years. The distal epiphysis unites at 11–12 in females and 14–15 in males (Hoerr and Pyle 1962:112–14). McKern and Stewart (1957:51) state that complete union had occurred by the age of 20 in all their cases.

The proximal epiphysis of the fibula unites after the proximal epiphysis of the tibia. It begins to unite between 14–15 in females and 16–17 in males (Pyle and Hoerr 1955:78–80). McKern and Stewart (1957:51) found that complete union does not occur until the twenty-second year in males (Figure 157).

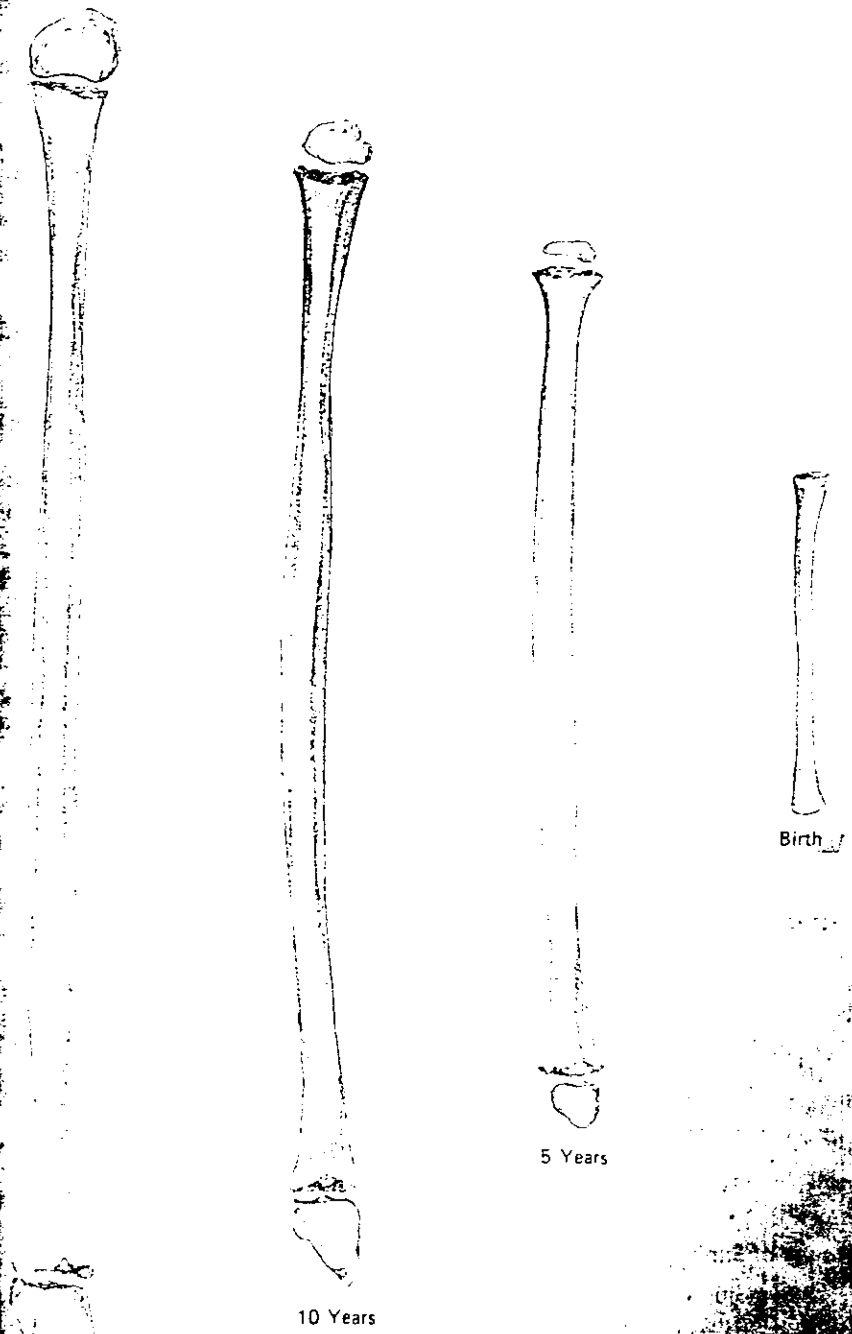


Figure 157. Developmental stages of the fibula at birth and at 5, 10, and 15 years.

TABLE 46.

Estimation of Stature[a] from Long Bones[b]

White females		Negro females	
3.36 Hum. + 57.97	± 4.45	3.08 Hum. + 64.67	± 4.25
4.74 Rad. + 54.93	± 4.24	3.67 Rad.[c] + 71.79	± 4.59
4.27 Ulna + 57.76	± 4.30	3.31 Ulna + 75.38	± 4.83
2.47 $Fem._m$ + 54.10[d]	± 3.72	2.28 $Fem._m$ + 59.76	± 3.41
2.90 $Tib._m$ + 61.53	± 3.66	2.45 $Tib._m$ + 72.65	± 3.70
2.93 Fib. + 59.61	± 3.57	2.49 Fib. + 70.90	± 3.80
1.39 ($Fem._m$ + $Tib._m$) + 53.20	± 3.55	1.26 ($Fem._m$ + $Tib._m$) + 59.72	± 3.28
1.48 $Fem._m$ + 1.28 $Tib._m$ + 53.07	± 3.55	1.53 $Fem._m$ + 1.79 $Tib._m$ + 58.54	± 3.23
1.35 Hum. + 1.95 $Tib._m$ + 52.77	± 3.67	1.08 Hum. + 1.79 $Tib._m$ + 62.80	± 3.58
0.68 Hum. + 1.17 $Fem._m$ + 1.15 $Tib._m$ + 50.12	± 3.51	0.44 Hum. − 0.20 Rad. + 1.46 $Fem._m$ + $Tib._m$ + 56.33	± 3.22

[a]To estimate stature of older individuals subtract .06 (age in years − 30) cm.
[b]After Trotter and Gleser (1952:Table 18).
[c]From Trotter and Gleser (1977:355).
[d]Mean length of long bone.

Adult Bone

Situated on the lateral side of the lower leg, the fibula is the most slender of all the long bones in proportion to its length. It articulates with the tibia proximally (at the knee) and with the tibia and talus distally (at the ankle). It is smaller and bears less weight in reptiles, is still smaller in monotremes and marsupials, and has either disappeared or is represented by a fibrous band in horses and ruminants (e.g., cows, oxen, sheep, goats, deer, and antelopes). In carnivora and primates the complete fibula exists but does not bear weight, and only in man does the fibular malleolus descend below the level of the tibial malleolus. In man it is important for muscle attachments and in the formation of the ankle joint.

The head of the fibula is a rounded expansion and medially has a circular articular facet. The distal end (lateral malleolus) is pyramidal in form, somewhat flattened from side to side, and forms the outside of the ankle joint.

Bones of Similar Shape where Confusion May Arise

The radius and ulna may appear similar because of the comparable size of the shafts. The shaft of the radius is triangular with a prominent interosseous crest. The surface opposite this crest (lateral) is thick and

rounded, and the triangular edges are not prominent. The ulna also has a triangular shaft with an interosseous crest, but the surface opposite the crest (medial) has sharper, more distinct edges. The shaft of the fibula tends to be irregular but more closely resembles the shaft of the ulna than it does the radius. The nutrient foramen in the ulna is larger and more prominent than in the fibula.

Side Identification

The malleolar fossa, the deep depression behind and below the distal articular surface, always goes down (distally) and is in the back (posterior) (Figure 158a).

When held in anatomical position the articular facets on both the head and distal ends are opposite the side the bone comes from.

If you have only the head (proximal end), hold the articular surface toward you and the styloid process will be on the same side the bone is from.

Hold the head up (superiorly) and the articular surfaces away from you; the twist of the distal half of the shaft is toward the side the bone is from (Figure 158b).

Measurements of the Fibula

1. Maximum length (osteometric board). Measures the maximum distance between the proximal and distal extremities. Follow the same procedure as with the humerus (C–D) (see Figure 154).

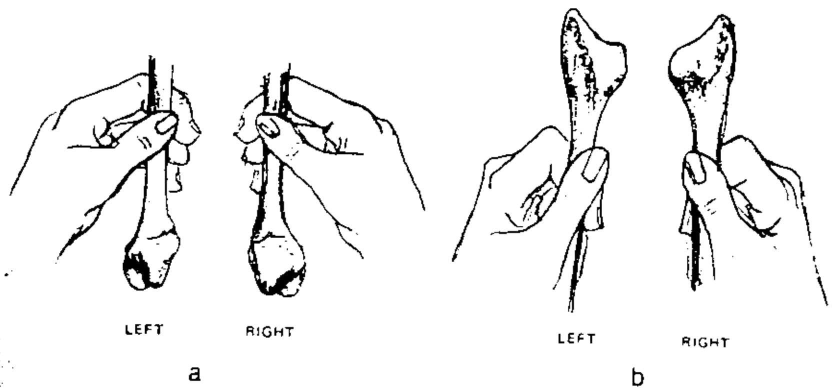


Figure 158. Methods used to distinguish side of the fibula using positions 1 (a) and 2 (b) as described in the text.

Age Estimation

Johnston's (1962) data on the fibula as an age estimator in the Indian Knoll skeletal population is the basis for Table 47 below.

TABLE 47.

Estimation of Age Using Length of Fibula[a]

	Fibula		
Estimated age in years	N	Mean	Standard deviation
Fetal	1	50.00[b]	—
NB–0.5	37	65.38	5.19
0.5–1.5	25	92.44	13.79
1.5–2.5	5	113.80	7.44
2.5–3.5	6	134.17	10.39
3.5–4.5	7	144.71	11.32
4.5–5.5	3	171.67	4.52

[a]After Johnston (1962:Table 2).
[b]All measurements in mm.

The distal epiphysis unites before the proximal.

	Beginning union	Complete union
Distal epiphysis:	11–12 females	17
	14–15 males	20
Proximal epiphysis:	14–15 females	17
	16–17 males	22

Stature Estimation

The results of Trotter and Gleser's (1952) research on the fibula as a stature estimator are reproduced below.

Stature Formulae for the Fibula (Male)

White	2.60 fibula + 75.50 ± 3.86
Negro	2.34 fibula + 80.07 ± 4.02
Mongoloid	2.40 fibula + 80.56 ± 3.24
Mexican	2.50 fibula + 75.44 ± 3.52

Tarsal Bones: Paired, Irregular Bones (Figure 159)

The tarsal bones are grouped in two rows; the proximal row consists of two bones:

1. Talus
2. Calcaneus

The distal row consists of four bones:

1. First cuneiform
2. Second cuneiform
3. Third cuneiform
4. Cuboid

Interposed between the two rows on the tibial side (medial) of the foot is a single bone:

1. Navicular

On the fibular side (lateral) the proximal and distal rows come in contact. Compared with the bones of the carpus, the tarsal bones present few common characteristics and a greater diversity of size and form.

Presented below are brief descriptions of the tarsal bones along with general rules on side identification for each bone.

The talus (Figure 160) is the second-largest bone of the tarsus. Superiorly it supports the tibia, and inferiorly it rests upon the calcaneus. At the sides it articulates with the two malleoli (tibia and fibula), and anteriorly it is thrust against the navicular. No muscles are attached to it. To side the talus, put the convex side up and head forward; the sharp angular side is on the side the bone is from.

To side the calcaneus (Figure 161), put the heel toward you; all articular surfaces are on top and on the front of the bone. The front point of bone is on the same side the bone comes from. Also, the front facet (underneath point) is on the same side the bone comes from. The shelf on the side of the bone is the sustentaculum tali, which helps support the head of the talus. This shelf is opposite the side the bone comes from.

The cuboid (Figure 162) is on the lateral side (outside) of the foot and is in line with the calcaneus and fourth and fifth metatarsals.

To side the cuboid, place the pointed articular facet toward you and the smooth nonfacet side up. The point of the articular facet will be opposite the side the bone comes from. The aspect of the bone with a facet points to the side from which it comes. There also is a slight groove on the side from which it comes.

Of the three wedge-shaped cuneiform bones, the first is the largest, the second is the smallest, and the third is intermediate in size.

To side the first cuneiform (Figure 163), place the kidney-shaped articular facet (for the first metatarsal) forward and away from you and the concave navicular facet toward you. The only other facet will be on top, and the broad side will be down. The superior facet points to the side the bone comes from.

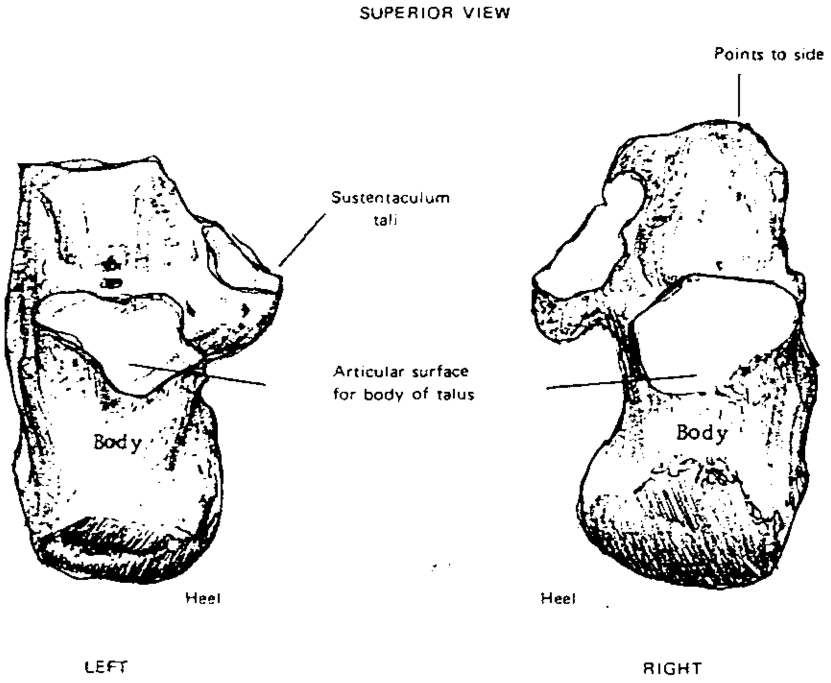


Figure 161. Characteristic features of the calcaneus.

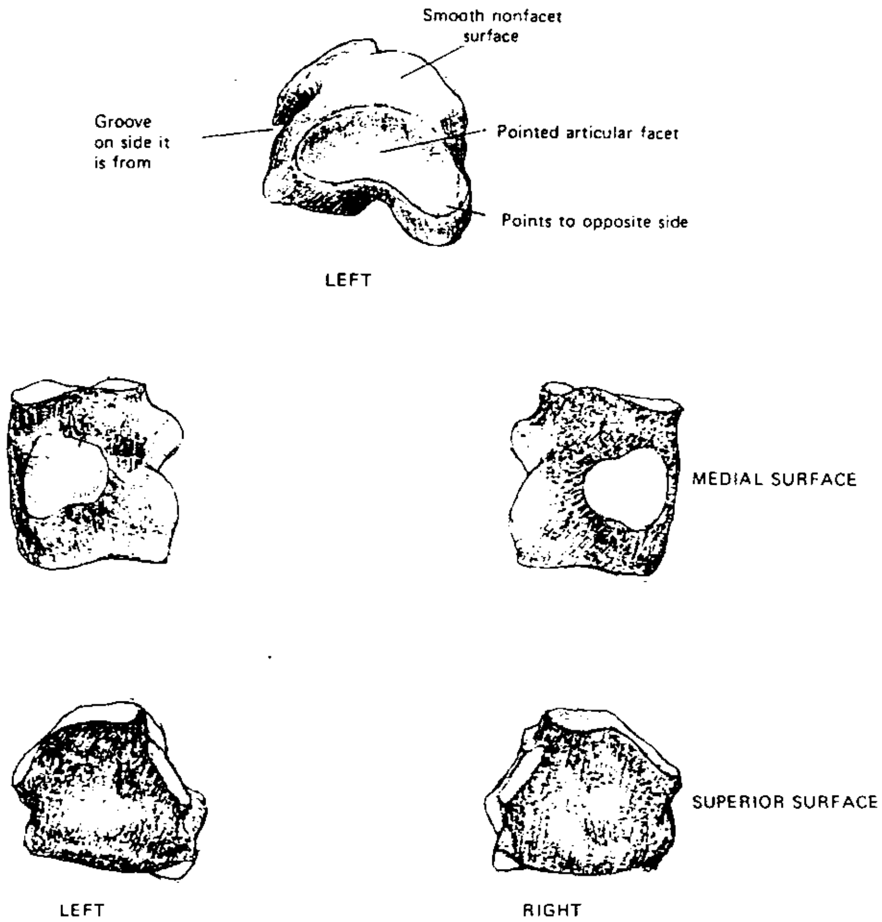


Figure 162. Characteristic features of the cuboid and features for side determination.

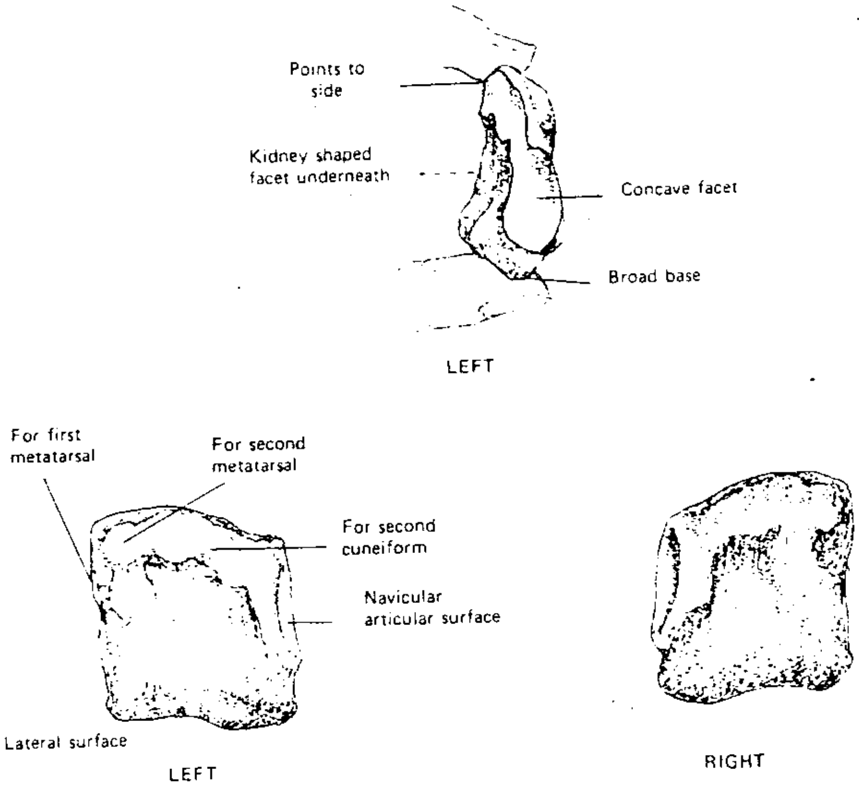


Figure 163. Articular surfaces of the first cuneiform and features for side determination.

To side the second cuneiform (Figure 164), place the wedge (point) down, the concave facet (navicular) toward you, and the flat, or smooth, side up. On the side the bone is from there is an L-shaped complete facet (upside down as the one is now situated). On the opposite side is an interrupted facet.

To side the third cuneiform (Figure 165), place the smooth, broad, nonarticular surface up, with the point, or wedge, down. Rotate in this position until the end closest to you and the one farthest away are articular surfaces. The articular surface for the navicular rounds the edge of the bone and forms a small articular facet (for second cuneiform) that does not extend along the top of the entire side of the bone. This articular surface is opposite the side the bone comes from. The bone also will be slightly concave toward the opposite side the bone comes from.

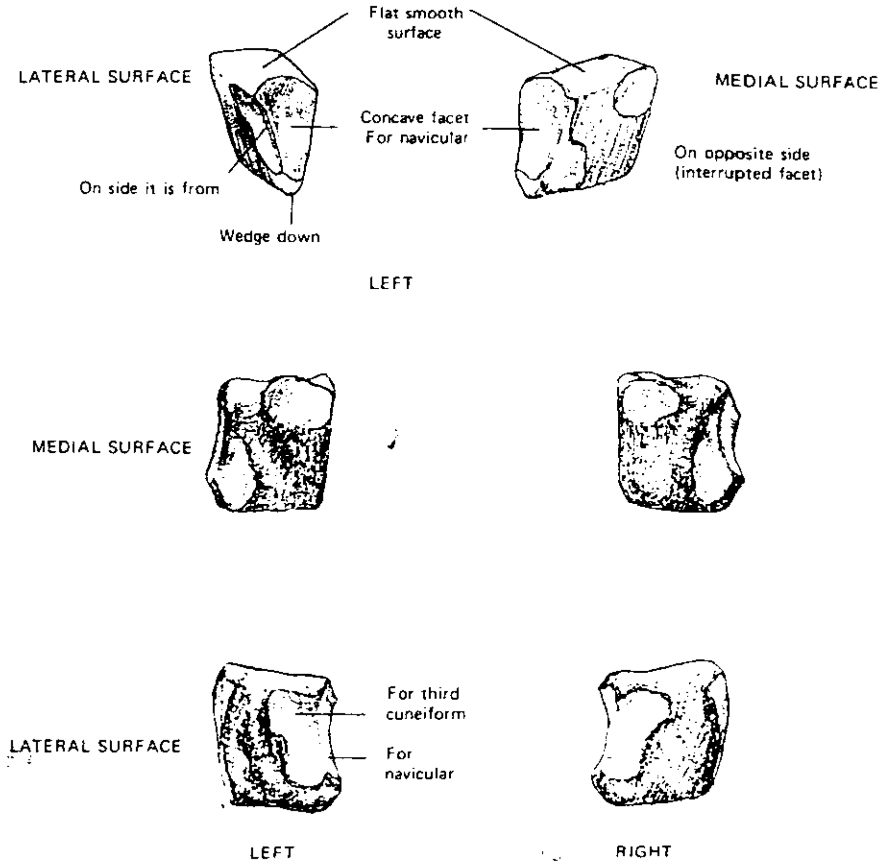


Figure 164. Articular surfaces of the second cuneiform and features for side determination.

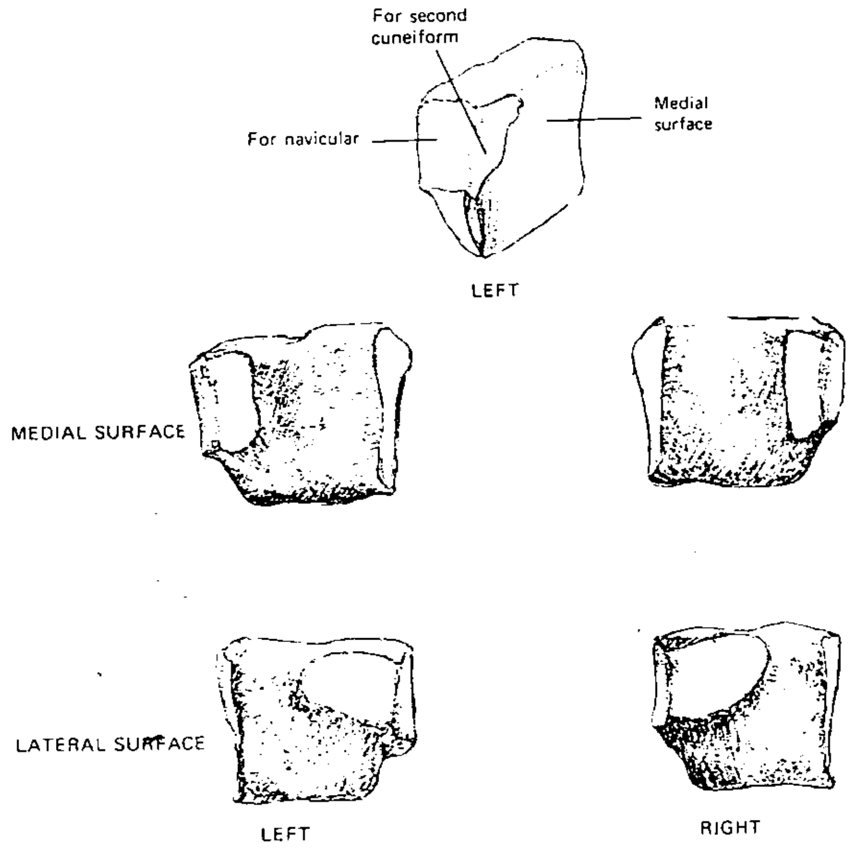


Figure 165. Articular surfaces of the third cuneiform and features for side determination.

The navicular (Figure 166) is characterized by a large, oval, concave articular facet on the posterior surface that receives the head of the talus. It sits on the inside of the foot and is much larger than the navicular of the wrist. Thus, no confusion between the two should result.

To side the navicular, hold the concave side toward you and the three facets that are situated underneath away from you. Hold the tubercle between your thumb and forefinger; the bone inclines or points toward the side it is from.

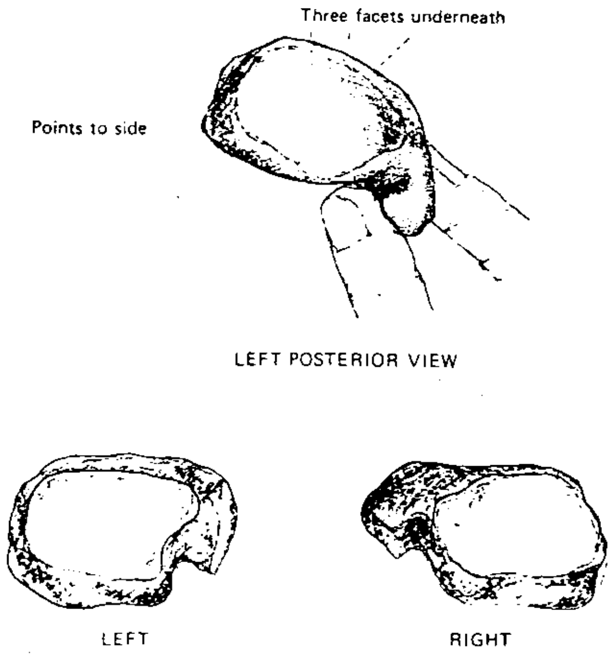


Figure 166. Articular surfaces of the navicular and features for side determination.

Metatarsal Bones: Paired, Short Bones (figures 167, 168)

The metatarsals consist of five cylindrical bones in each foot. They articulate with the tarsus proximally and with the first, or proximal, row of phalanges distally. As with the metacarpals in the hand, they have been described aptly as long bones in miniature. As they extend from the tarsus, they diverge from each other slightly. Metatarsals are numbered from the medial (big toe) to the lateral side (small toe).

As with long bones, metatarsals present a shaft and two extremities. The base of the tarsal extremity articulates with the tarsus proximally and on the side of the basilar end articulates with the adjacent metatarsal bones.

The shaft gradually tapers from the base to the distal end (head) and is curved so as to be convex on the dorsal side (top of foot) and concave on the plantar side (bottom of foot). The shaft is somewhat triangular in cross section.

The head, or distal extremity, articulates with the proximal (first) phalange. Note that the heads all present large, rounded articular surfaces.

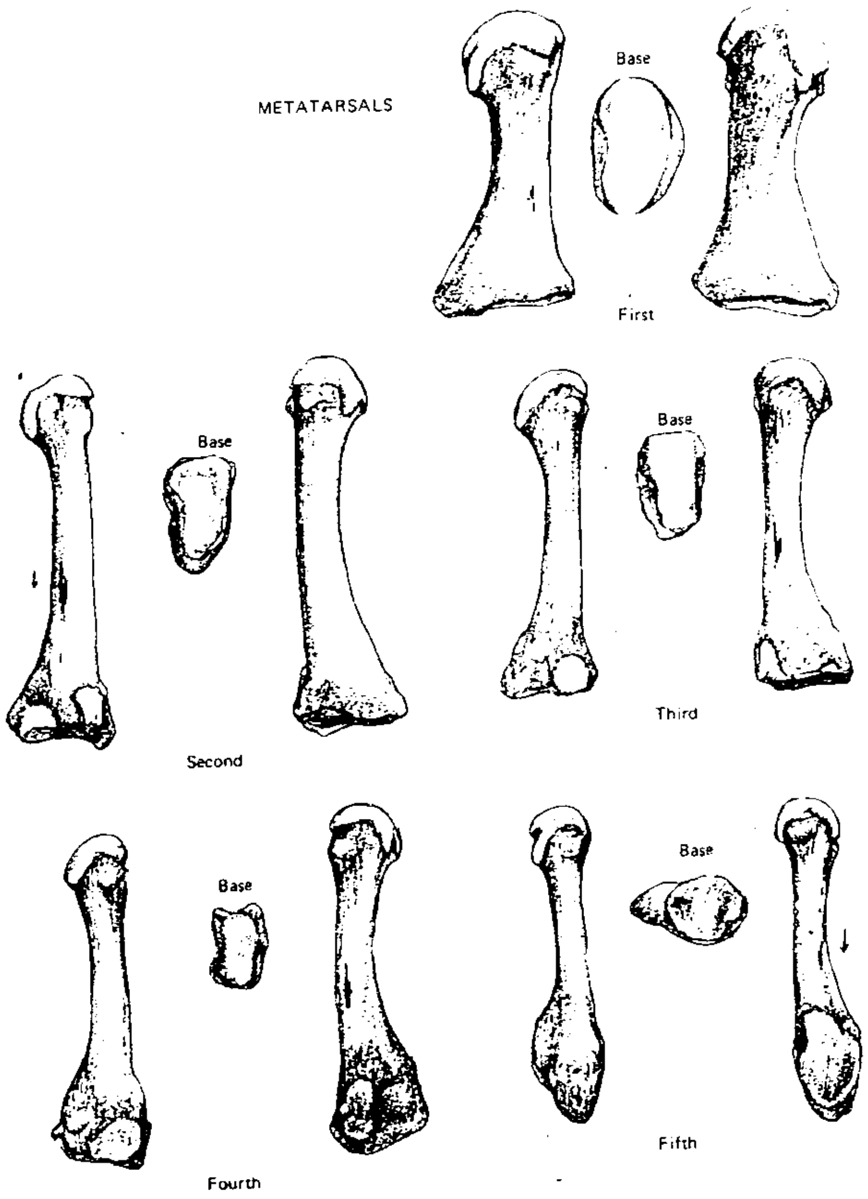


Figure 167. Metatarsals of the left foot.

Although the nutrient foramina are difficult to find in many metatarsals, note that they are inclined toward the distal end of the first but toward the proximal end of the second through the fifth (the same pattern as in the metacarpals).

Brief descriptions of the metatarsals are presented below along with rules for side identification.

The first metatarsal (the big toe) is the shortest, thickest, and most massive of the metatarsals. The base has a saddle-shaped articular facet for the first cuneiform bone. The head is marked on the plantar surface by two deep grooves, separated by a ridge. These grooves are associated with two sesamoid bones. Anatomical position for all metatarsals (Figure 168a–d) will be the same when held with the proximal end (base) toward you.

For the first metatarsal, the saddle-shaped articular surface will be inclined slightly toward the opposite side the bone comes from (Figure 168a).

The second metatarsal usually is the longest of the metatarsals. It has two small articular surfaces on the same side of the base the bone comes from (Figure 168b).

The third, fourth, and fifth metatarsals successively decrease in length.

There is a continuous articular surface on the third metatarsal that is from the upper left side across the base and around to the upper right side (Figure 168c). The largest articular facet on the side of base is on the same

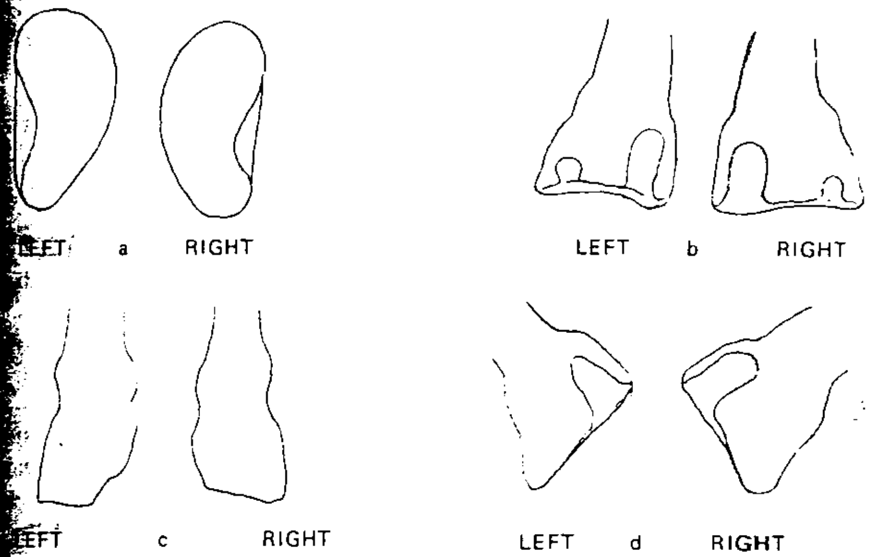


Figure 168. Identification of side: a, first metatarsal; b, second metatarsal; c, third metatarsal; d, fourth metatarsal.

side the bone comes from. In some cases there may be a small articular surface along the lower margin opposite the side the bone comes from.

The fourth metatarsal usually is shorter than the third, and the base resembles that of the third very closely. When viewing the dorsal surface of the base, the base projects farther on the same side the bone comes from (Figure 168d).

The fifth metatarsal easily is recognized by the rough, nonarticular eminence known as the tuberosity on the lateral side of its base. With the groove between the articular facet and the tuberosity down, the tuberosity will be on the same side the bone comes from.

Phalanges (Toes): Paired, Short Bones (Figure 169)

There are 14 phalanges in each foot, 2 for the big toe, and 3 for each of the other digits. They are divided into 3 rows: first, or proximal—5 (the largest); second, or middle—4 (no middle phalanx in the big toe); and third, distal, or terminal—5 (the smallest). In all phalanges the nutrient canal (foramen) is directed toward the distal extremity. They are not easily seen. The phalanges present a shaft and two extremities.

First, or proximal, row (Figure 169a)—The phalanges are constricted in the middle of the shaft and expand at either extremity. The proximal extremity presents a slightly concave, oval articular surface that receives the convex head of the metatarsal bone. The distal extremity is grooved in the center and elevated on each side into two small condyles. These condyles, on the distal extremity of the proximal and middle phalanges, resemble the distal or lower end of the femur. To correspond with these condyles, the bases of the terminal and middle phalanges have two small depressions and resemble the proximal or upper end of the tibia.

Second, or middle, row (Figure 169b)—These are stunted and much smaller bones than the corresponding phalanges of the fingers. The base or proximal extremity presents two shallow depressions separated by a medial ridge that articulate with the first row of phalanges. The distal end articulates with the base of the third row of phalanges and is grooved in the center and elevated on each side into two small condyles.

Third, or distal, row (Figure 169c)—Small in size, the third phalanx is recognized easily because the distal end is tapered. One side (dorsal) is fairly smooth, over which the toenail fits, and the other (plantar) surface is rough because of the attachments of the fiber bands of the pulp of the digits.

The proximal end is similar in shape to that of the second phalanx in that it presents two shallow depressions separated by a medial ridge. One could never confuse the phalanges of the middle and distal row if it is remembered that both ends of the middle phalanges have articular surfaces, whereas only the proximal end is an articular surface on the phalanges in the distal row.

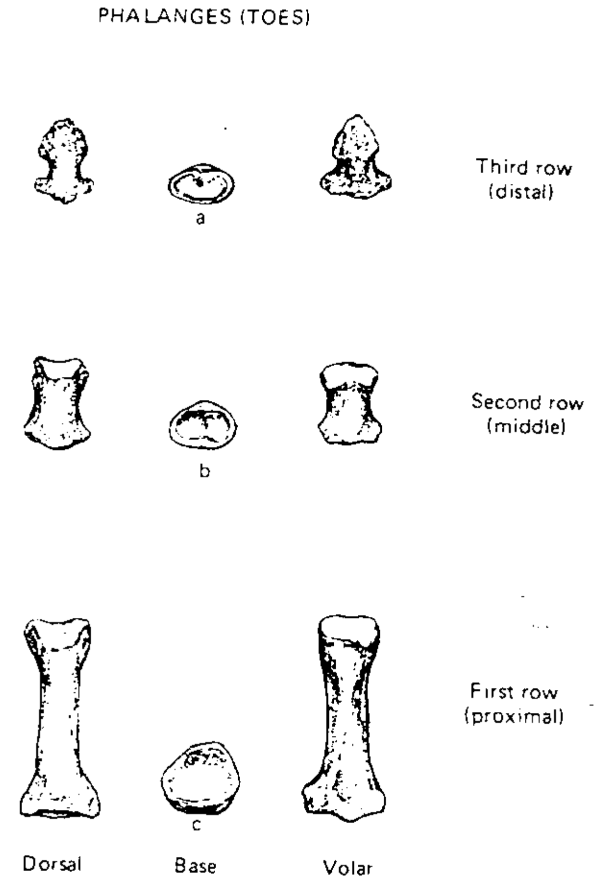


Figure 169. The phalanges, third digit (toe) of the foot: a, distal row; b, middle row; c, proximal row.

4

HUMAN DENTITION*

32 TEETH IN ADULTS
20 TEETH IN CHILDREN

The study of teeth is very important to the anthropologist and paleontologist because teeth are constructed of dense and hard material, resist decay in the ground, and often outlast bone. Consequently, teeth have played an important role in the study of fossil man.

Paleontologists spend much time studying the various genetic and functional characteristics of the teeth. The study of teeth is a special field of knowledge in itself; the anatomical terms used to describe the single tooth and the dental arch differ slightly from those used in anatomy.

There are four "types" of teeth in the human dental arch: incisors, canines, premolars, and molars. This classification is based on both the morphology and function of the respective teeth. The actual genetic or developmental reasons for this morphology are unknown. However, it has been suggested that the dentition is under the influence of a morphogenetic field that controls its morphological expression. This theory has been advanced by Butler (1937, 1939, 1961, 1963) and has been applied to the human dentition by Dahlberg (1945, 1949, 1963). Dahlberg feels that different tooth groups are under different morphogenetic fields and that these fields are concentrated as certain teeth within the tooth group. This produces the distinct "types" of teeth as well as some teeth that appear more stable and less variable than others within the group. Whatever the developmental reasons behind the formation of distinct types of teeth, they usually are expressed in a "dental formula" such as the following.

$$\text{Adult dental formula} = I\frac{2}{2}\ C\frac{1}{1}\ PM\frac{2}{2}\ M\frac{3}{3} = 16 \times 2 = 32$$

Where

I = incisor—a tooth designed for cutting
C = canine—teeth with pointed cusps for tearing and incising
PM = premolars—teeth with broad occlusal surfaces with multiple

*The material in this chapter was prepared by Douglas H. Ubelaker.

cusps for grinding and reducing food material as an aid to digestion

M = molars—same as premolars but with broader occlusal surfaces

The dental formula expresses the number of teeth in the upper jaw (numbers above the line) and in the lower jaw (numbers below the line), but in only one-half of the mouth. The numbers recorded in the formula must be multiplied by 2 to determine the total number of teeth in the mouth. Often teeth will be given as M^1, M^2, etc., indicating the first and second upper molars, and M_1, M_2, etc., indicating the lower molars (Figure 170a).

Man develops two sets of teeth. Usually, no teeth are visible at birth, but at approximately six months of age the first deciduous (baby) teeth—the lower central incisors—erupt. The deciduous set consists of 20 teeth and may be given in a formula as follows.

$$\text{Deciduous dental formula} = i\frac{2}{2}\ c\frac{1}{1}\ m\frac{2}{2} = 10 \times 2 = 20$$

The names of the teeth are abbreviated in the same way as in the adult dental formula, but with lower-case letters. (Note that there are no premolars in the human deciduous formula.)

The deciduous dentition consists of 8 incisors, 4 canines, and 8 deciduous molars. The deciduous incisors and canines are miniature replicas of the adult incisors and canines. The same criteria used to differentiate between adult incisors and canines may be employed for the corresponding deciduous teeth. The first deciduous molars in the maxillary are the precursors of the adult maxillary (upper) premolars. The deciduous second molars are replicas of the permanent first molars in the respective maxilla or mandible.

Sexual dimorphism is not marked enough in either the adult or the deciduous dentition to allow sex determinations to be made. However, as a general rule, males tend to have slightly larger teeth.

ANATOMICAL TERMS FOR TEETH (Figure 170b)

Every tooth has three areas:

1. Crown—that part of the tooth situated above the gum and covered with enamel (Figure 170c).
2. Neck—a slightly constricted portion just below the crown and the area known as the cemento-enamel junction.
3. Root—that portion of the tooth below the crown and neck. It is enclosed in the tooth socket and covered with cementum.

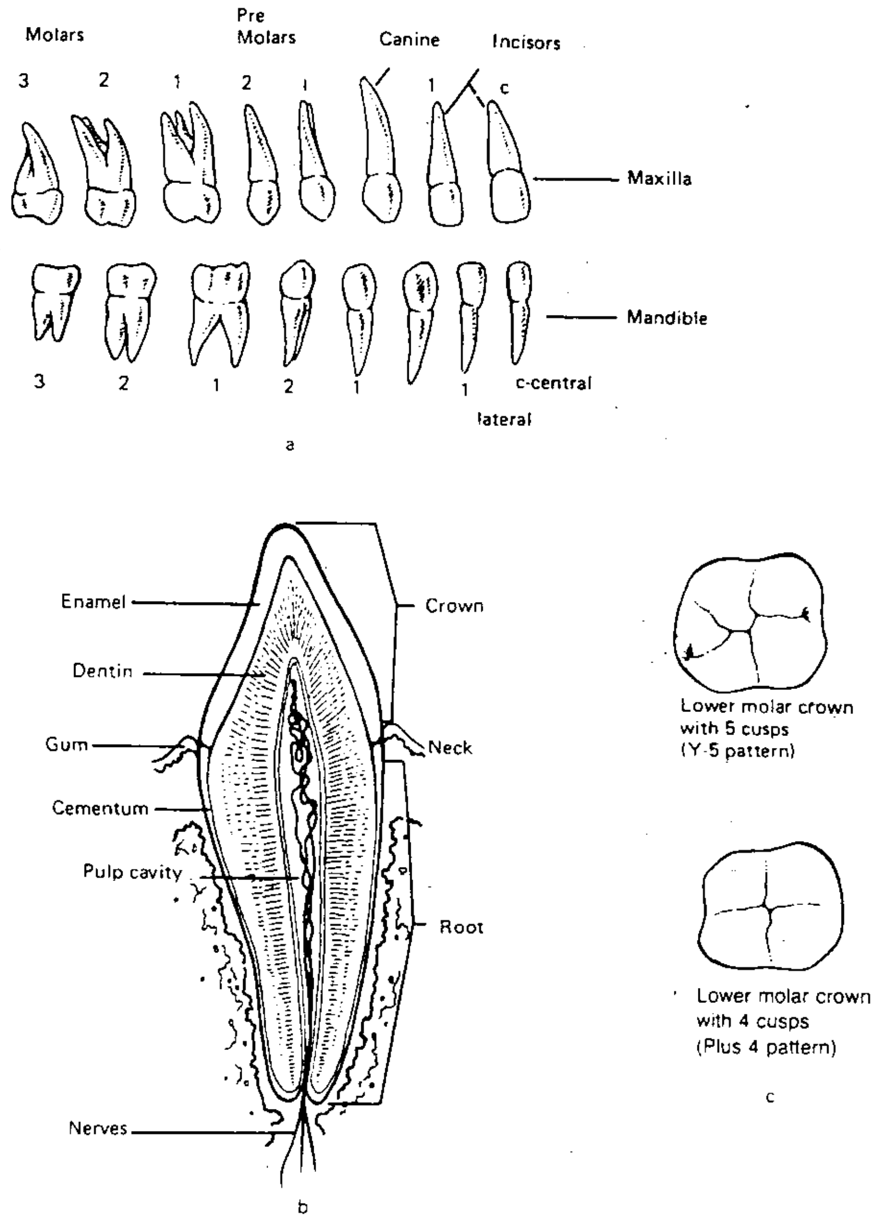


Figure 170. Human dentition: a, tooth types; b, anatomical terms for teeth; c, cusp patterns.

Each tooth consists of:

1. Enamel—a white, compact, and very hard substance that covers and protects the dentin of the crown of the tooth.
2. Cementum—a layer of bony tissue covering the root of a tooth.
3. Dentin—the chief tissue of the tooth that surrounds the pulp cavity. It is covered by enamel on most of the exposed parts of the tooth and by cementum on the part implanted in the jaw. Dentin forms the main bulk of the tooth.
4. Pulp cavity—the pulp chamber and canal within the tooth. It contains a soft tissue called pulp.

Each tooth has five surfaces (Figure 171):

1. Labial (lips) or buccal (cheek)—labial, the side toward the lips, is used with incisors and canines; buccal, the side toward the cheek, is used with premolars and molars.
2. Lingual—the side toward the tongue.
3. Occlusal—the surface of the tooth that comes into contact with the teeth of the opposite jaw (the biting surface).
4. Mesial—the surface of the tooth that lies against an adjoining tooth and faces toward the median line.
5. Distal—the surface of the tooth that lies against an adjoining tooth and faces away from the median line.

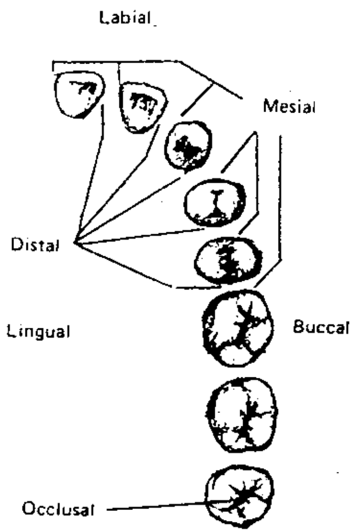


Figure 171. Tooth surfaces.

WHICH TOOTH IS IT?
STEPS TO FOLLOW IN IDENTIFYING TEETH

One of the best books for the study of teeth is Anderson's (1962) *The Human Skeleton, A Manual for Archaeologists*. The serious student should consult this book for additional details.

When one is faced with the problem of identifying bones or teeth, it is most efficient to proceed by following certain steps (see steps for bones in Chapter 1). The following five steps are recommended.

Step 1.

Determine whether the tooth is deciduous or adult. Deciduous teeth are smaller than their adult equivalents and are more yellow in color because the enamel and cementum layers are not as thick as in adult teeth.

Step 2.

Is the tooth an incisor, canine, premolar (in adults) or molar? This is a fairly easy step.

Step 3.

Is the tooth from the upper jaw (maxilla) or the lower jaw (mandible)? This is a difficult step and requires study. Some students would rather reverse steps 3 and 4, and this can be done without difficulty (see Anderson's 4 steps, which are in a different sequence).

Step 4.

What position in its group does the tooth hold? Once the type of tooth has been determined, decide whether it is a central or lateral incisor, a first or second premolar, or a first, second, or third molar. This is a more difficult step and requires a considerable knowledge of dental anatomy.

Step 5.

Is the tooth from the right or left side? This probably is the most difficult step, and comparative dental arches should be consulted.

A series of comparative dental arches, both upper and lower, should be consulted when identifying teeth, just as a skeleton should be consulted when identifying bones when there is some doubt in the identifier's mind.

Replacing Teeth in a Dental Arch

When one is required to replace teeth in a dental arch, it is critical to know the various types of teeth and their locations. Of equal importance are wear facets located between the teeth (mesial and distal edges). Teeth move as the jaw is in operation and therefore rub against one another, producing slick wear surfaces. These will match perfectly when the proper two adjacent teeth are placed together.

Never glue a tooth into a socket until the wear surfaces are matched (excessive wear on the occlusal surface due to attrition occasionally may eliminate this valuable aid).

The following analysis presents data on each type of tooth and follows the steps outlined above.

INCISORS (Figure 172)
4 CENTRAL—2 UPPER AND 2 LOWER
4 LATERALS—2 UPPER AND 2 LOWER

The incisors are the two teeth on either side of the midline in both jaws. They are characterized by single roots and crowns with a sharp occlusal (mesiodistal) ridge or edge.

They are the most frequently lost teeth in archaeological specimens and the most frequently encountered outside of the dental arch, as they have a short single root.

Step 1—Is its deciduous or adult?

Deciduous incisors are considerably smaller than adult incisors and are more yellow in color. If the dental arch is present (either upper or lower), there will be spaces between the teeth as the individual approaches age 6. The roots of teeth are formed only after growth of the crown is completed. (Once the roots of teeth have formed, the teeth do not get any larger, but as a child grows from age 2 to 6 the mandible and maxilla enlarge and create spaces between the teeth.)

Step 2—What type of tooth is it?

An incisor has:

1. A single root (not as large as a canine).
2. A single crown with an occlusal (mesiodistal) edge.
3. A shovel-shaped lingual surface, particularly in Mongoloid racial groups. In some cases an enamel extension also is present on the labial surface, producing a "double-shovel-shaped" incisor. Occasionally the lingual extension will enclose an area in the center and produce a "barrel-shaped" incisor (Figure 173).

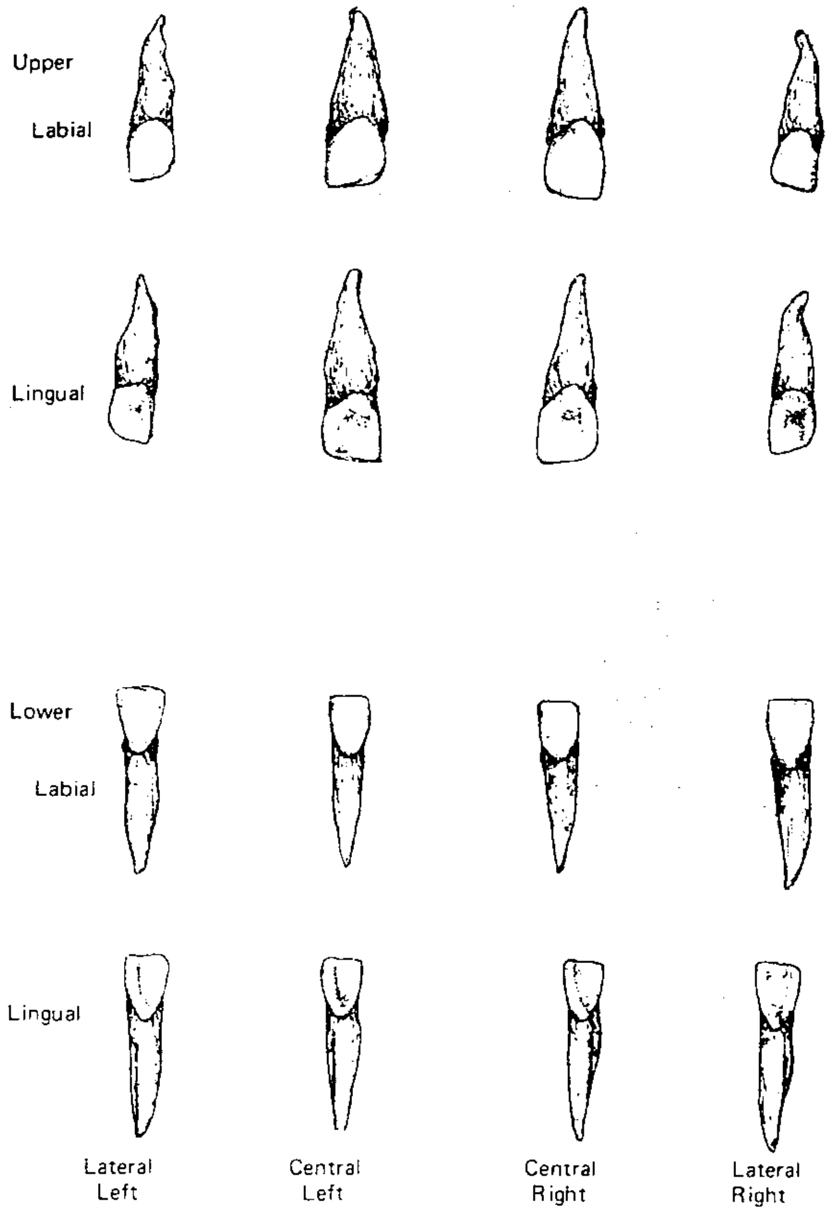


Figure 172. The incisors.

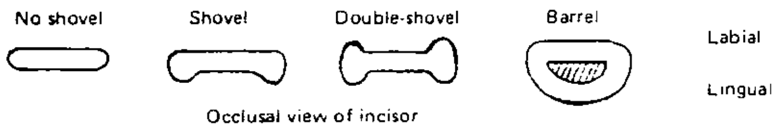


Figure 173. Morphological variation of incisor cross sections (occlusal view).

Step 3—Is it upper or lower?

An upper incisor:

1. Is large.
2. Has a shovel-like crown.
3. Has a cingulum.

A lower incisor:

1. Is small.
2. Has a narrow crown.
3. Has no cingulum.

The cingulum is a bulge or raised area on the lingual surface of the tooth near its neck or gum line. It usually is absent from mandibular (lower) incisors.

Step 4—What position does it hold?

An upper central incisor:

1. Is the largest of the incisors.
2. Has a square mesial angle of crown.
3. Has a rounded distal angle of crown.
4. Is most likely to have a shovel shape.

An upper lateral incisor:

1. Is smaller than an upper central incisor.
2. Usually has a pit at the base of the cingulum.
2. May have a shovel shape.

A lower central incisor:

1. Is the smallest of the incisors.

A lower lateral incisor:

1. Is larger than a lower central incisor but smaller than an upper.
2. Has a wider crown (spreading out into a fan shape) at the occlusal surface.

Always be aware of the wear facets between neighboring teeth.

Step 5—Is it right or left?

Upper:

1. The angle formed by the mesial and occlusal edges is a right angle (Figure 174a).
2. The angle formed by the distal and occlusal edges is rounded.

Lower:

1. The roots of the lower incisors are flattened in a plane that is perpendicular to the axis of the crown. The roots are wider labiolingually than mesiodistally. When held in proper position (by the root with the lingual surface facing you), there will be a groove on the flat surface of the root (distal surface) on the same side the tooth comes from (Figure 174b).

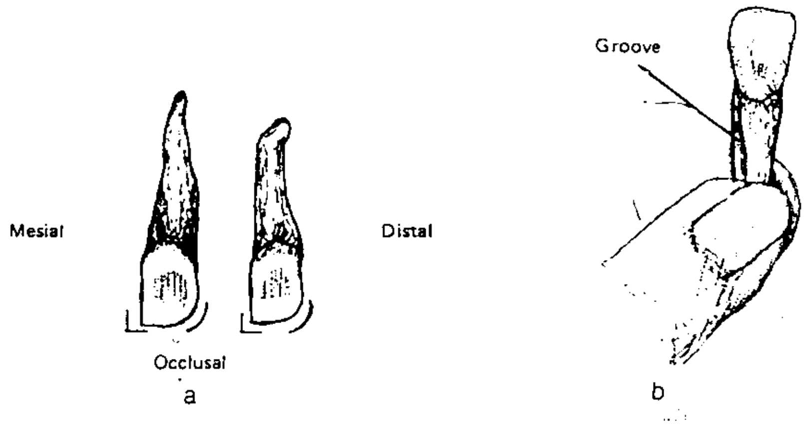


Figure 174. Side identification of incisors: a, mesial, distal, and occlusal edges (right incisor, lingual view); b, groove on flat surface of root (left incisor, lingual view).

CANINES (Figure 175)
2 UPPERS—1 RIGHT AND 1 LEFT
2 LOWERS—1 RIGHT AND 1 LEFT

The canines sometimes are called eye teeth (because of their position below the eyes) or dog teeth (because of their large size in that animal). This is the tooth that gave the saber-toothed tiger its name. Although greatly reduced in man, it still is the longest tooth in the mouth and has the largest root in relation to crown surface of any tooth.

These are the second most frequently lost teeth in archaeological specimens, or the second most frequently encountered teeth outside of the dental arch because they have one long single root.

Step 1—Is it deciduous or adult?

A deciduous canine is smaller and more yellow than an adult canine.

Step 2—What type of tooth is it?

A canine has:

1. A single large root (larger than an incisor).
2. A single pointed cusp.
2. A large root in relation to its crown.

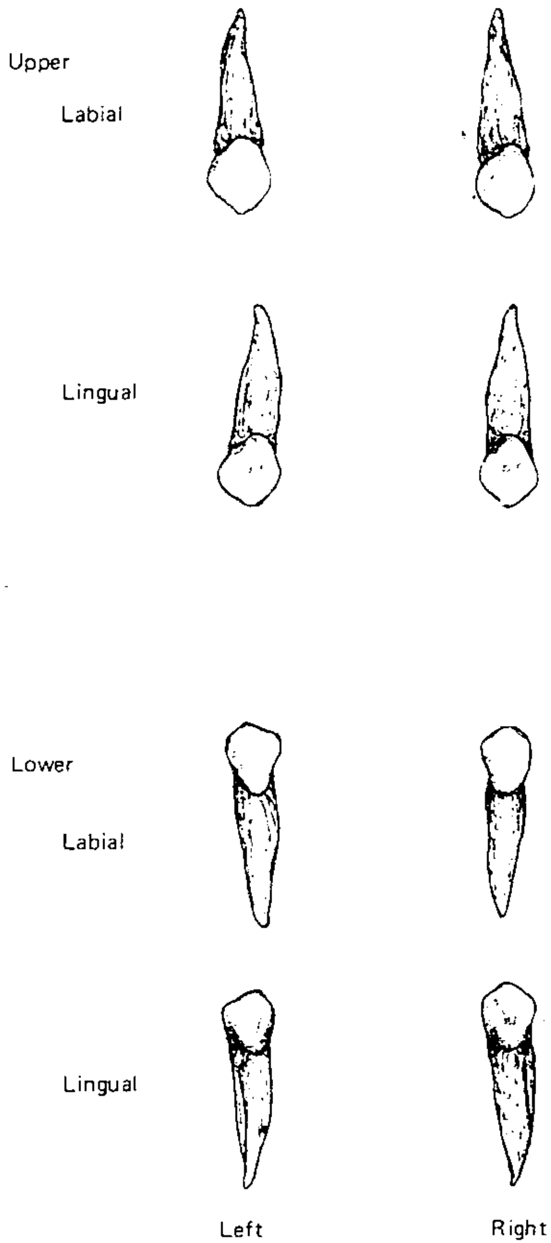


Figure 175. The canines.

Step 3—Is it upper or lower?

An upper canine has:

1. A wider crown.
2. A larger size.
3. A sharper single-point cusp.
4. A cingulum (see incisor section for definition).

A lower canine has:

1. A narrower crown.
2. A smaller size.
3. A blunt single-point cusp.
4. No cingulum.

Step 4—What position does it hold?

This does not apply to canines since there is only one per quarter.

Step 5—Is it right or left?

Lower:

1. When held in proper position (by root with lingual surface facing you), there will be a groove on the flat surface of the root (distal surface) on the same side the tooth comes from (Figure 176a).
2. If the occlusal surface is not worn down and can be observed, it will be noted that the mesial slope of the crown is shorter than the distal slope. Viewed from the lingual surface, the longer distal slope will be on the same side the tooth comes from (Figure 176b).
3. The gritty diet of many aboriginal populations often produced so much wear on the occlusal surfaces of the crowns that these criteria may not be accurately applied.

Upper:

1. When held by the root with the crown pointing down and lingual surface facing you, there will be a groove on the flat surface of the root (distal surface) on the same side the tooth is from (Figure 176c).

Always be aware of the wear facets between neighboring teeth.

PREMOLARS (Figure 177)
4 UPPER—2 RIGHT AND 2 LEFT
4 LOWER—2 RIGHT AND 2 LEFT

The premolars, sometimes known as bicuspids because they usually have two cusps, or points, on the crown, may in man have one, two, or three cusps. They are the two teeth behind the canines and in front of the molars.

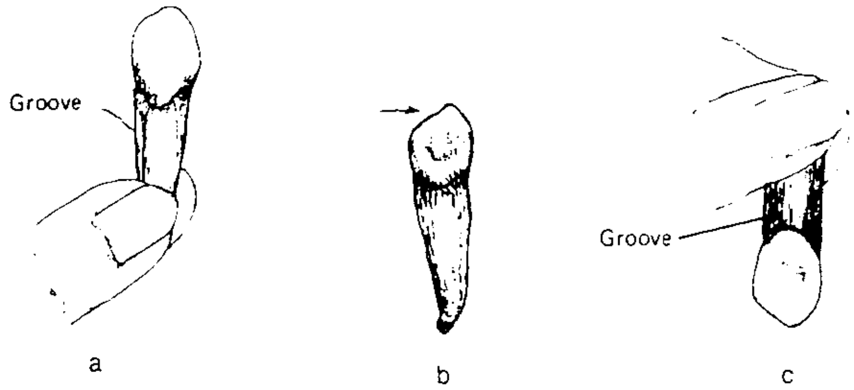


Figure 176. Side identification of canines: a, distal surface groove (left canine, lingual view); b, distal slope (lower) (left canine, lingual view); c, distal surface groove (upper) (left canine, lingual view).

These are not lost from archaeological specimens as often as are incisors and canines because their roots tend to be more complex, holding the tooth in its socket. Lower teeth are easier to remove, as they have single roots.

Step 1—Is it deciduous or adult?

It has to be adult because there are no deciduous premolars.

Step 2—What type of tooth is it?

A premolar:

1. Usually has two cusps, one buccal and one lingual.
2. Is usually smaller than a molar.

Step 3—Is it upper or lower? (Be cautious with worn teeth.)

An upper premolar:

1. Has cusps of equal size.
2. Usually has two roots, one buccal and one lingual (same as cusps).
3. May have fused roots, but the line of union can be seen.

A lower premolar has:

1. A large buccal cusp.
2. A single root, wider buccolingually and narrower mesiodistally.
3. A root tip that curves distally when viewed from the lingual surface.

Step 4—What position does it hold?

The first upper premolar (Figure 178a):

1. Usually has two roots.
2. Buccal cusp may be larger.
3. Mesial surface of the crown is concave.

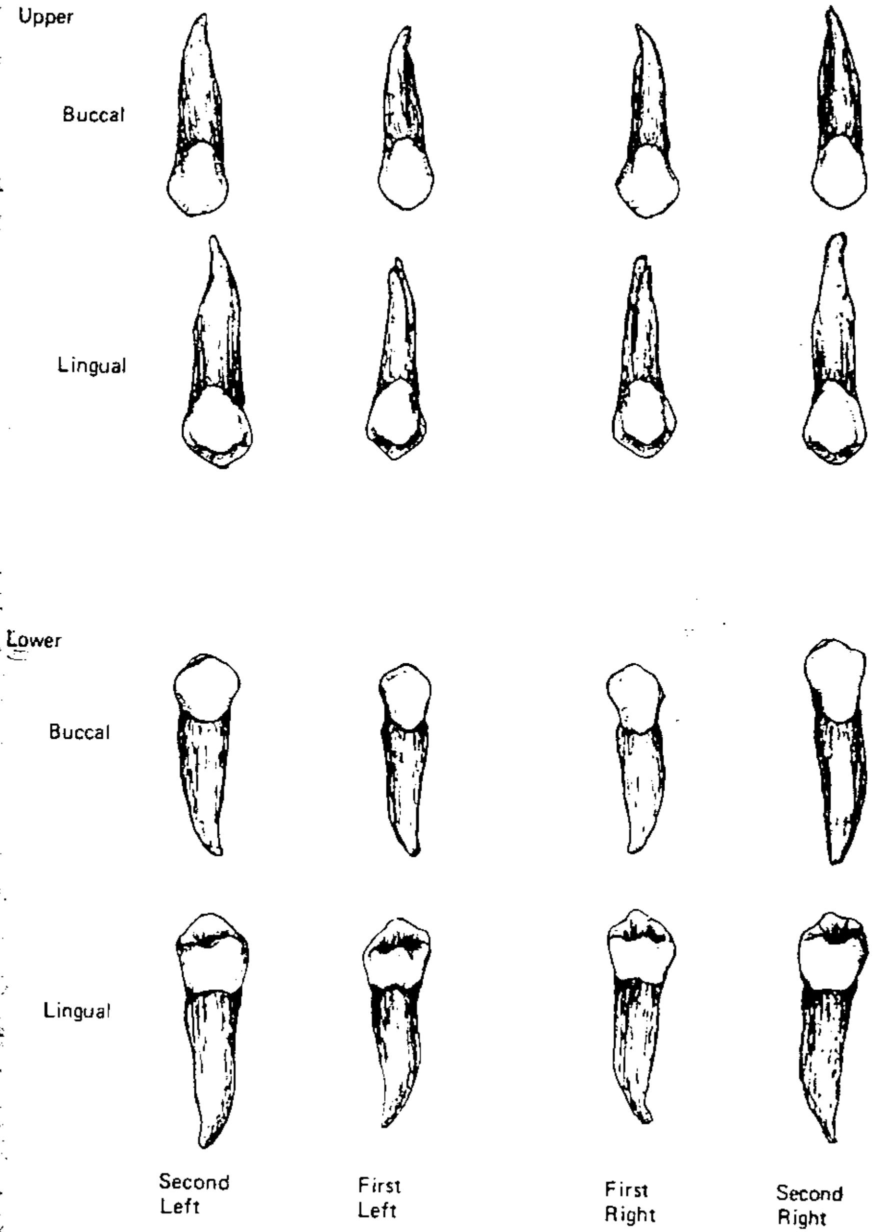


Figure 177. The premolars.

The second upper premolar:
1. Usually has one root.
2. Both cusps are about equal.
3. Mesial surface of the crown is convex.

The first lower premolar:
1. Has a small, single, lingual cusp.
2. May have a groove on the mesial surface of its root.
3. May have a larger buccal cusp.

The second lower premolar:
1. Has a small, sometimes double lingual cusp.
2. Has no groove on the mesial surface of its root.
3. Has cusps of equal size.

Step 5—Is it right or left?

Upper (Figure 178b):
1. When held by the root with the crown pointing down and lingual surface facing you, the tip of the root will incline toward the same side the tooth comes from.

Lower (Figure 178c):
1. When held by the root with the lingual surface facing you, the tip of the root will incline toward the same side the tooth comes from.
2. The first lower premolar may have a groove on the mesial surface of the root or on the root surface opposite the side the tooth is from (when held by the root with the lingual surface facing you).

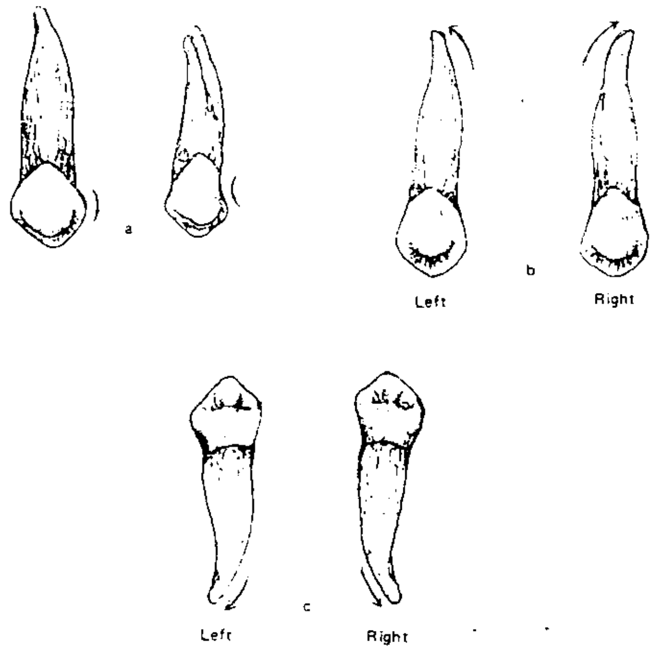


Figure 178. Determination of position (upper or lower) and side identification of the premolars (all lingual views): a, second and first premolar (upper); b, root inclination (upper); c, root inclination (lower).

MOLARS (Figure 179)
6 UPPER—3 RIGHT AND 3 LEFT
6 LOWER—3 RIGHT AND 3 LEFT

Most skulls will have 12 molars, but many may have only 8. The third molar is a genetically unstable tooth that may be lost in many individuals, thus reducing the total number of adult teeth from 32 to 28. The molars are the grinding teeth that make up the dental arch behind the premolars. They are fair age indicators, as the first erupts at about 6 years of age (6-year molar), the second at about 12 years (12-year molar), and the third at 18 years (wisdom tooth). The third molar, being genetically unstable, may erupt at any age from 18 years to the time of death.

Molars are the least frequently lost teeth in archaeological specimens because of their multiple roots. Indeed, they are difficult to remove from their tooth sockets.

Step 1—Is it deciduous or adult?

Deciduous molars:
1. Are much smaller.
2. Are more yellow in color.
3. Have much thinner roots.
4. Have roots that are much wider apart.

Step 3—Is it upper or lower?

An upper molar has:
1. Three roots (may be fused).
2. Roots arranged as follows: one lingual, one mesiobuccal, and one distobuccal.
3. A crown that is more square.
4. Usually four or three cusps.

A lower molar has:
1. Two roots (may be fused).
2. Roots arranged as follows: one mesial and one distal.
3. A crown that is more oblong (i.e., longer mesiodistally).
4. Usually five or four cusps.

Step 4—What position does it hold?

Upper first molar:
1. Lingual root is largest and often widely divergent.
2. Contact facets are found mesially and distally.
3. Carabelli's Cusp often is present.

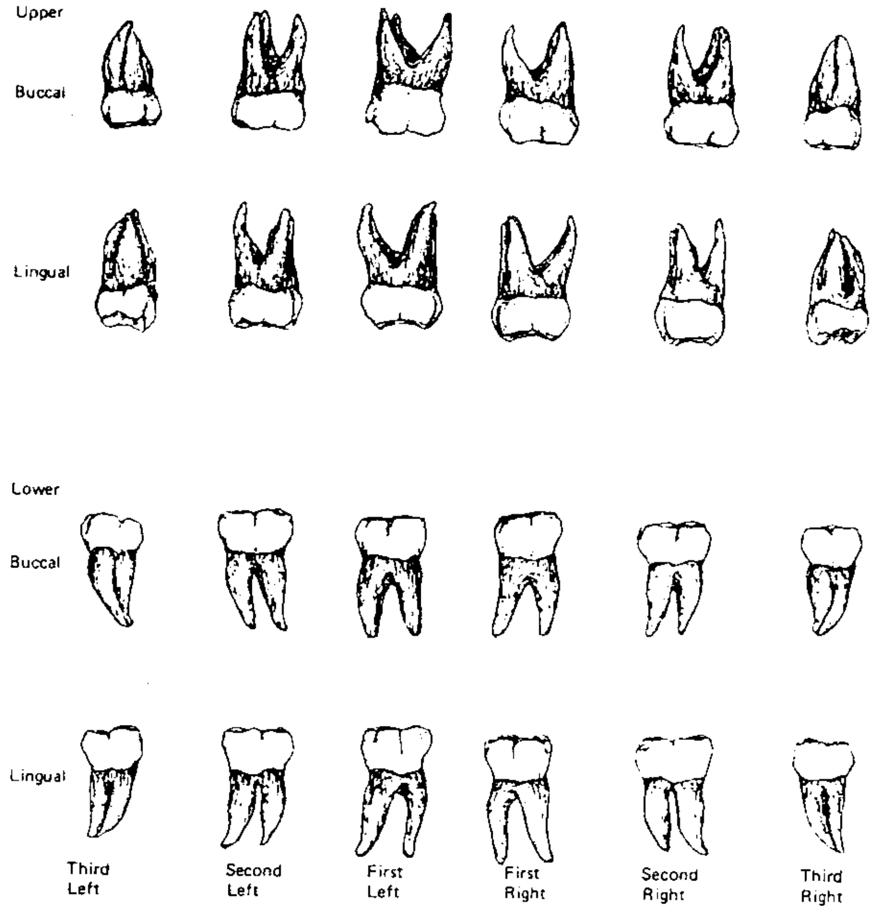


Figure 179. The molars.

Upper second molar:
1. Lingual root is largest but not widely divergent.
2. Contact facets are located mesially and distally. When there is no M^3, a distal contact facet is not present.
3. Carabelli's Cusp sometimes is present.

Third upper molar:
1. Roots often are fused and smaller than in the first and second molars.
2. Contact facets are on the mesial surface only.
3. Carabelli's Cusp is not present.

A Carabelli's Cusp is a small tubercle that sometimes is present on the mesiolingual surfaces of the upper molars, especially the first and sometimes the second.

Lower first molar:
1. Two separate roots, mesial surface curved backwards.
2. Usually has five cusps.

Second lower molar:
1. Two roots may be fused, both curved backwards.
2. Usually four cusps.

Lower third molar:
1. Two fused roots that curve backwards.
2. Variable.

Step 5—Is it right or left?

Upper molars (Figure 180a):
1. The distolingual cusp is the smallest.
2. The crown is more convex on the lingual surface, and when held by the root with the crown pointing down with the distal surface toward you, the convex side of the crown is on the side the tooth is from.

Lower molars (Figure 180b):
1. The roots are inclined toward the back.
2. The crown is more convex on the buccal surface, and when held by the roots with the distal surface toward you, the convex side of the crown will be on the same side the tooth is from.

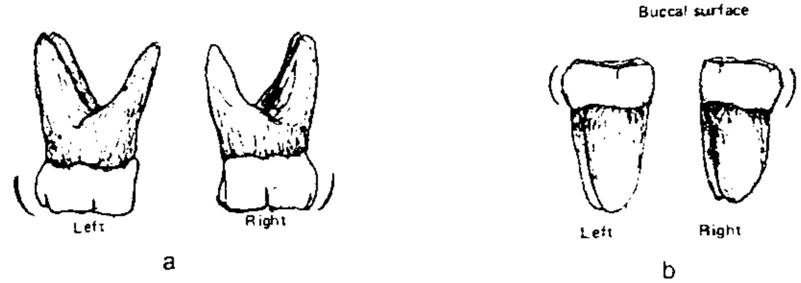


Figure 180. Side identification of molars (all distal views): a, upper first; b, lower.

MEASUREMENTS OF THE TEETH

There are many methods of measuring teeth mentioned in the literature. Four of the most common indicators of tooth size are tooth height, mesiodistal diameter, buccolingual diameter, and crown module. Tooth

height frequently is omitted in studies of archaeological specimens, since so many prehistoric agricultural people rapidly wore down their teeth. When it is taken, it usually is expressed as the distance from the crown–root juncture to the maximum height on the crown.

The mesiodistal diameter (also called breadth, width, or length in the literature) is expressed as the maximum diameter between the mesial and distal contact points.

The buccolingual diameter usually is expressed as the maximum diameter taken at a right angle to the mesiodistal axis.

Crown module is an expression of the relative crown mass. It is computed by averaging the mesiodistal and buccolingual diameters. Tooth height ideally should be included to represent a complete description of crown mass, but since the recording of tooth height is limited so severely by attrition, crown module usually is used for comparative and descriptive purposes.

In addition to measurements of the teeth, there also are a number of observable characteristics of the teeth that are of interest to physical anthropologists. The recording of these observations is important to establish the existing variation of modern man and to see how the dentition of man has changed from that of his fossil ancestors. These observations fall into two general categories: variations in tooth number and position and variations in tooth morphology.

VARIATIONS IN TOOTH NUMBER AND POSITION

Supernumerary Teeth

Supernumerary teeth are extra teeth that may occur in the incisor, canine, premolar, or molar tooth groups. Supernumerary teeth may be exact replicas of the normal teeth, or they may present a morphology that does not resemble any particular tooth group. They are found in both the adult and deciduous dentitions but only rarely in the deciduous dentition. Frequently, supernumerary teeth will occur bilaterally and may result from the retention of deciduous teeth in the adult dentition. Extra teeth may occur in many positions in or around the dental arcade.

Congenital Absence of Teeth

Occasionally, one or more teeth normally present in the dentition will be missing. Of all the teeth, the third molars are the most frequently missing (Table 48), but any of the other teeth may be absent congenitally. The investigator must be careful not to confuse congenital absence of teeth with unerupted teeth or teeth that were lost before death. Unerupted teeth

TABLE 48.

Percentage Distribution of Missing Third Molars among Select Populations[a]

Group	Author		Number of jaws	Percent lacking one or more M_3
Chinese	Hellman	1928	19	32.0
Chinese	Knap[b]	1937	64	31.2
Mongols (Buriat)	Hellman	1928	21	17.0
Japanese	Hamano[b]		1300	18.4
Eskimo	Hellman	1928	55	13.0
Angmagssalik Eskimo	Pedersen	1949	257	26.7
East Greenland Eskimo skulls	Pedersen	1949	81	23.5
Modern unmixed S. W. Greenland Eskimo	Pedersen	1949	210	18.6
Modern mixed S. W. Greenland Eskimo	Pedersen and Hinsch	1940	319	11.0
Labrador Eskimo	Dahlberg	1949	23	16.0
Northwest Eskimo	Goldstein	1932	232	15.5
American Indian	Hellman	1928	55	13.0
Blackfoot Indian	Dahlberg	1949	25	8.0
Sioux Indian	Smith	1894	10	50.0
Early Texas Indian	Goldstein	1948	173	19.5
Carabis Indian	Maurel[b]		68	70.6
Hawaiian	Dahlberg	1945	25	24.0
Melanesian	Dahlberg	1945	165	4.0
Australian Aboriginal	Hellman	1928	20	13.0
West African Negro	Hellman	1940	?	2.6
American Negro	Hellman	1928	119	11.0
European white	Hellman	1928	61	20.0
White (Hungary)	Hellman	1928	?	49.0
American white	Banks	1934	461	19.7

[a]After Dahlberg (1951:Table 34).
[b]Cited in Pedersen (1949).

may be detected easily from a radiograph. Teeth that originally were present but lost before examination present more of a problem. Of course, if the teeth were lost postmortem, the cavities for the roots will be present in the alveoli. However, if a tooth was lost antemortem, the alveolus may have resorbed, leaving little or no indication of the root cavity. Antemortem tooth loss usually can be detected by the characteristic distorted and unequal appearance of the alveolus. Also, if the missing tooth was at one time in contact with the adjacent teeth, wear facets then may be found on the appropriate surfaces of the teeth.

Rotation of Teeth

Occasionally teeth will be in their proper position in the tooth row, but they will appear to be rotated as much as 180° (Figure 181). When a tooth has rotated, the normal distal surface may become the lingual surface or vice versa. The second premolars are rotated most often, but other teeth also can be in this position.

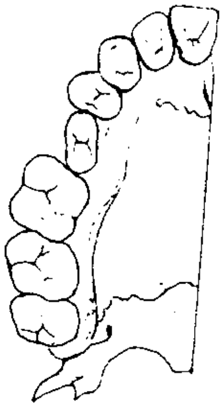


Figure 181. Rotated right maxillary second premolar.

Crowding of Teeth

Frequently the adult dentition will appear to be crowded, with one or more teeth pushed out of their normal position. This condition usually is a consequence of a reduction in size of the mandible without a corresponding reduction in the size of the teeth. The space in the alveolus is not large enough to permit the teeth to erupt in their normal positions, so consequently they must erupt in altered positions. Crowding frequently accompanies impacted third molars and the rotated condition of teeth described above. Deciduous teeth seldom are crowded, since normally they have plenty of room for eruption. Of all the teeth, the incisors usually are the most affected by crowding.

VARIATIONS IN TOOTH MORPHOLOGY

Molar Cusp Pattern

The pattern of cusps and grooves on the occlusal surfaces of the molars has long been of interest to physical anthropologists for establishing

differences among modern populations and in revealing our primate ancestry. This observation is severely limited when studying many prehistoric populations, since the gritty nature of their diet frequently contributed to premature tooth wear, thus obscuring their cusp patterns. On teeth that do display a clear cusp pattern, it first should be noted that the maxillary and mandibular molars display different cusp patterns. The maxillary molars usually have three or four cusps separated by distinct grooves. In the first maxillary, the four cusps usually are about equal in size. In the second maxillary molars, the fourth cusp, or hypocone, usually is reduced in size. In third maxillary molars the hypocone may be absent completely or be reduced to a mere cuspule on the distal surface. To record the size of these cusps Dahlberg (1951:165) has suggested the following system: "4 designates four well developed cusps; 4− indicates a reduction in the size of the hypocone; 3+ indicates absence of the hypocone but the presence of a cuspule on the distal border; 3 indicates total absence of the hypocone" (see Figure 182).

The mandibular molars normally display either four or five cusps (Figure 183). These cusps are arranged so that the grooves between them form either a "T" or a "Y." Consequently the four types of cusp patterns

Figure 182. Maxillary molar-cusp patterns. Numbers indicate the number of cusps present.

Figure 183. Mandibular molar-cusp patterns. Numbers indicate the number of cusps present.

are Y5, Y4, +5, and +4. Of these patterns the Y5 is common on the teeth of many fossil men, while the remaining three are recent developments in modern groups. It has been suggested that the general trend has been for the Y5 pattern to evolve into the +4 pattern through either the +5 or the Y4 stages. On modern molars the genetically stable mandibular first molar most frequently displays the ancestral Y5 pattern. Second and third molars usually display a higher frequency of the other three patterns. It should be

noted that frequently cusp patterns appear intermediate in configuration and therefore are difficult to classify. Also, the genetically unstable third molar frequently presents an irregular cusp pattern that does not resemble any particular type (tables 49–51).

TABLE 49.

Percentage Distribution of Cusp Patterns of Lower First Molars[a]

Group	Author		N	Y5	+5	Y4	+4
Chinese	Hellman	1928	26	100.0			
Mongol	Hellman	1928	36	100.0			
Alaska Eskimo	Goldstein	1948	67	89.6	6.0	1.5	3.0
E. G. Eskimo	Pedersen	1949	143	95.7	2.8	0.0	1.4
Texas Indian	Goldstein	1948	160	68.7	30.6	0.6	0.0
Pecos Indian	Nelson	1937	332	88.6	10.8	0.0	0.6
Pima Indian	Dahlberg	1951	162	99.4	0.6		
Ancient European white	Hellman	1928	54	83.0	0.0	11.0	6.0
European white male	Hellman	1928	98	87.0	2.0	7.0	4.0
Chicago white	Dahlberg	1951	75	84.0	2.0	8.0	2.0
Australian Aborigine	Hellman	1928	18	100.0			
African Negro	Hellman	1928	97	99.0		1.0	

[a]After Dahlberg (1951:Table 25).

TABLE 50.

Percentage Distribution[a] of Cusp Patterns of Lower Second Molars[b]

Group	Author		N	Y5	+5	Y4	+4
Chinese	Hellman	1928	21		19.0		81.0
Mongol	Hellman	1928	39		31.0	5.0	64.0
Alaska Eskimo	Goldstein	1948	132	12.8	63.8	3.0	20.5
E. G. Eskimo	Pedersen	1949	115	19.0	42.0	4.0	35.0
Texas Indian	Goldstein	1948	206	1.5	26.2	3.4	68.9
Pecos Indian	Nelson	1937	313	8.3	24.3	1.3	66.1
Pima Indian	Dahlberg	1951	89	2.0	69.0	1.0	28.0
Ancient European white	Hellman	1928	54	2.0	11.0	9.0	77.0
European white	Hellman	1928	110		1.0	5.0	94.0
Australian Aborigine	Hellman	1928	21	5.0	43.0		52.0
African Negro	Hellman	1928	96	17.0	8.0	12.0	63.0

[a]The percentage figures of a few of the groups do not add up to 100 because the authors in some instances included other categories of patterns. However the figures are not too far off to be of comparative value.
[b]After Dahlberg (1951:Table 26).

TABLE 51.

Percentage Distribution of Cusp Patterns of Lower Third Molars[a]

Group	Author		N	Y5	+5	Y4	+4	Irreg.
Chinese	Hellman	1928	16		50.0		50.0	
Mongol	Hellman	1928	31		77.0		23.0	
Alaska Eskimo	Goldstein	1948	59	20.4	69.5	0.0	10.2	
E. G. Eskimo	Pedersen	1949	55	15.0	74.0	11.0	0.0	
Texas Indian	Goldstein	1948	91	12.1	47.3	6.6	34.1	
Pecos Indian	Nelson	1937	249	8.4	51.0	4.8	35.8	
Pima Indian	Dahlberg	1951	7		57.0		14.0	28
Ancient European white	Hellman	1928	35	6.0	34.0	11.0	49.0	
European white	Hellman	1928	74	4.0	34.0		62.0	
Australian Aborigine	Hellman	1928	23	14.0	72.0		14.0	
African Negro	Hellman	1928	88	20.0	59.0	3.0	17.0	

[a]After Dahlberg (1951:Table 27).

Extra Cusps

Extra cusps have been described on many surfaces of both the maxillary and mandibular molars. Of particular interest are the extra cusps that have been termed protostylids and Carabelli's Cusps (Figure 184a). A protostylid is an extra cusp that occurs on the anterior aspect of the buccal surface of the mandibular molars (Figure 184b). According to Dahlberg (1950:24), the cusp is significant because it occurs in the South African Australopithecines, the *Meganthropus* material from Java, and the Chinese *Sinanthropus* material. He notes that it has only rarely been recorded in modern populations except in one population of 80 Pima Indians, in which

a b

Figure 184. Extra cusps: a, Carabelli's Cusp on maxillary right first molar; b, protostylid on mandibular left first molar.

37 displayed the cusp. The protostylid occurs in various degrees of prominence, but it usually is recorded as being either present or absent.

Carabelli's Cusp (also known as the tuberculum Carabelli and the tuberculum anomale) consists of a tubercle located on the anterior portion of the lingual surfaces of maxillary molars. The extra cusp occurs in various forms that range from a pit (Carabelli's Pit) considered by some to be related to the cusp, to the well-developed cusp itself. Because the cusp does occur in various forms at this location, there have been several descriptive classification systems devised (Figure 184a, Table 52). These classifications are discussed by Kraus (1959). Carabelli's Cusp appears to be a recent evolutionary development that occurs in varying frequencies in all modern populations. The related Carabelli's Pit has been observed in fossils dating back to the Australopithecines, but no undisputed Carabelli's Cusps have been found in fossil hominoids.

TABLE 52.

Percentage Distribution of Carabelli's Cusp[a]

Group	Author		M_3		M_2		M_1	
			N	%	N	%	N	%
Northwest Eskimo	Dahlberg	1951	12	0.0	17	0.0	26	7.0
Labrador Eskimo	Dahlberg	1951	12	0.0	22	0.0	23	0.0
E. G. Greenland Eskimo skulls	Pedersen	1949	34	0.0	44	0.0	25	0.0
Living E. G. Eskimo	Pedersen	1949	98	0.0	162	0.6	106	0.0
West Greenland Eskimo	Pedersen	1949			None pronounced			
Central Eskimo	Pedersen	1949			None pronounced			
Eskimo and white	Pedersen	1949						29.4
Blackfoot Indian	Dahlberg	1951			50	0.0	41	12.0
Pecos Pueblos	Nelson	1937						8.8
Pima Indians	Dahlberg (cusps)	1951			152	0.0	322	8.0
Pima Indians	Dahlberg (pits)	1951			152	4.0	322	27.0
Indian Knoll	Dahlberg (small cusps)	1951	33	6.0	33	9.0	33	24.0
American (Army)	Dietz	1944					732	72.3
American whites	Dahlberg	1951			13	8.0	91	41.0
Swiss	M. de Terra	1905		1.35		0.22		11.2
Dutch	Bolk	1915				21.7		17.4
Lapps	Kajava	1912		0.0		0.0		3.4
Bantu	Shaw	1931					389	2.0

[a]After Dahlberg (1951:Table 33).

Shovel-Shaped Teeth

One of the most frequently discussed genetic characters of teeth is the shovel shaping of the incisors (Figure 173, tables 53, 54). First mentioned by Hrdlička (1907:55), its relatively high frequency of occurrence in Mongoloid racial groups has been recorded by many investigators. Morphologically, shovel shaping involves a lingual extension of the lateral borders of the incisors. Ideally, each incisor should be classified by the degree of shovel shaping it exhibits on its lingual surface, and the depth of the lingual fossa should be measured. However, due to the high degree of attrition on the incisors of many populations, it often is necessary to limit the classification to an observance of the presence or absence of shovel shaping.

Occasionally an incisor will display a buccal extension of its lateral borders in addition to the usual lingual extension. The incisor displaying this phenomenon is termed a double-shovel-shaped incisor. Double-shov-

TABLE 53.

Percentage Frequency of Shovel-Shaped Median Incisors[a]

Group	Author		N		Median incisors: Shovel-shaped marked	Semi-marked	Total	Trace	None
Chinese	Hrdlička	1920	male	208	66.2	23.4	89.6	1.8	7.8
			female	1094	82.7	12.5	94.2	1.0	3.8
Mongolian	Hrdlička	1920		24	62.5	29.0	91.5	8.5	
Eskimo	Hrdlička	1920		40	37.5	47.5	84.0	15.0	
E. G. Eskimo	Pedersen	1949		116	83.6	14.7	95.3		
Mixed			male	1388			85.0		
Indians	Wissler	1931	female	1205			85.0		
Pima			male	101	96.0		96.0	4.0	
Indians	Dahlberg	1951	female	125	99.0		99.0	1.0	
Pueblos									
Indians	Dahlberg	1951		21	81.0	19.0	100.0	0.0	
Sioux	Hrdlička	1931		116	98.3		98.3	1.7	
Pecos Pueblos	Nelson	1937		324	74.1	15.4	89.5	8.3	2.2
Pecos Pueblos	Hooten	1930		124	86.3		86.3	13.7	
Early Texas									
Indian	Goldstein	1948		124	95.1		95.1	4.9	
Indian Knoll	Dahlberg	1951		30	84.0	16.0	100.0		
American			male	618	4.9	7.6	12.5	33.0	54.5
Negro	Hrdlička,	1920	female	1000	3.6	8.0	11.6	32.6	56.0
American			male	1000	1.4	7.6	9.0	24.5	66.5
white	Hrdlička	1920	female	1000	2.6	5.2	7.8	21.8	70.4

[a]After Dahlberg (1951:Table 22).

TABLE 54.
Percentage Frequency of Shovel-Shaped Lateral Incisors[a]

					Lateral incisors					
Group	Author			N	Shovel-shaped marked	Semi-marked	Total	Trace	None	Anomalous form
Chinese	Hrdlička	1920	male	1094	56.9	24.0	90.9	1.5	9.5	
			female	208	68.8	13.5	82.3	1.0	3.4	
Mongolian	Hrdlička	1920		24	75.0	25.0	100.0			
Eskimo	Hrdlička	1920		37	57.0	43.0	100.0			
Indians	Hrdlička	1920		300	76.0	17.0	93.0	6.0	1.0	
Indians	Wissler	1931	male	1356	82.0		82.0			
			female	1186	87.0		87.0			
Pecos Pueblos	Nelson	1937		338	72.0	17.4	89.4	9.3	1.4	
Pueblos Indian	Dahlberg	1951		21	81.0	14.0	95.0			5.0
Pima	Dahlberg	1951	male	93	81.0		81.0	13.0	1.0	5.0
			female	119	81.0		81.0	7.0		12.0
Indian Knoll	Dahlberg	1951		30	80.0	71.0	97.0			3.0
American			male	618	4.5	12.8	17.3	38.0	42.1	
Negro	Hrdlička	1920	female	1000	3.8	11.1	14.9	35.1	47.5	
American			male	1000	1.4	8.5	10.2	36.4	50.0	
white	Hrdlička	1920	female	1000	1.0	7.4	8.4	29.9	59.6	

[a] After Dahlberg (1951:Table 23).

el-shaped incisors usually are maxillary, but they have been found in the mandible (Figure 173).

Some incisors display such a pronounced lingual extension of the lateral borders that the tooth assumes the appearance of a distorted premolar, or a barrel shape. Barrel shaping most often occurs on maxillary lateral incisors.

Peg-Shaped Teeth

Occasionally teeth will occur that appear abnormally small and unlike they normally would appear (Figure 185). Such teeth have been described as peg shaped and occur most frequently on the genetically unstable third molars and lateral incisors. Peg shaping has been reported in all modern populations and appears to be related to congenital absence.

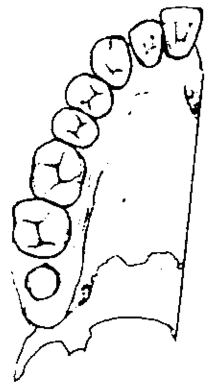


Figure 185. Peg-shaped maxillary right third molar.

Taurodontism

Taurodontism is a condition found in the molars, in which the pulp cavity is enlarged and the roots are reduced (Figure 186a). This condition frequently has been observed in Neanderthal and other fossil forms. In addition, it has been found occasionally in some modern populations. Taurodontism occurs in various degrees of prominence that have been classified by Shaw (1928) into four types: cynodont, hypotaurodont, mesotaurodont, and hypertaurodont.

Enamel Extensions and Pearls

In some molars and premolars an extension of the crown enamel will occur between the roots (Figure 186b, c). Sometimes this extension will culminate in a cluster of enamel termed an enamel pearl. If the teeth are imbedded in the alveolus, the enamel pearls often are obscured from

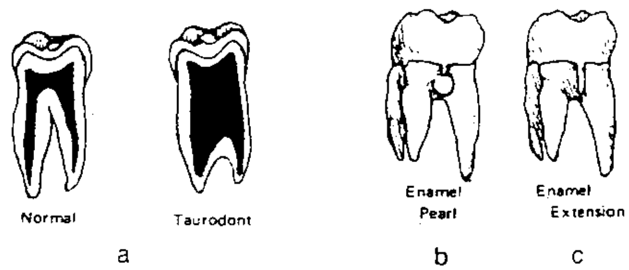


Figure 186. Taurodontism, enamel extension, and pearl: a, normal and taurodont; b, enamel extension; c, enamel pearl.

observation by the surrounding bone. Enamel pearls have been observed in many human populations, but little is known of their frequency of distribution or of their evolutionary significance.

Extra or Missing Roots

Occasionally a tooth will display an extra root or the absence of a root that normally is present. It is important to record the number of roots present whenever possible.

Moving from the first molar to the third, one can see a tendency for the molar roots to become less divergent and more fused. A similar trend occurs in the premolars.

Occlusal Wear

During the process of mastication, the mandibular and maxillary teeth continually rub against each other and against whatever gritty-food particles are in the mouth. This continual abrasive action eventually wears down the occlusal surfaces of the teeth, destroys the cusp patterns on molar crowns, and eventually exposes the underlying dentin. The rate at which this destructive attrition takes place greatly depends on the diet of the population involved. For example, in most aboriginal American Indian populations the process of attrition proceeds quite rapidly. It has been suggested that this is due to the excessive amount of grit in their diet that probably originated from their grinding stones. In contrast, most modern Americans experience a very retarded rate of attrition—again because of their diet. The degree of attrition can provide effective criteria for determining the age at death of an individual as long as the rate of attrition of that particular population is known. Many investigators rely principally on the degree of attrition present in the molars to determine age. The molars are especially useful because the cusp patterns on their occlusal surfaces allow several progressive stages of attrition to be identified and correlated with age at death. When the molars are used, it must be remembered that attrition will not be marked to the same degree on all molars since they erupt at different ages. In other words, the first molars are exposed to about twelve more years of mastication than the third molars and about six years more than the second molars. When an age determination is attempted, that difference needs to be kept in mind. Again, it is important to remember that all populations do not have the same rate of attrition, and therefore the criteria of estimating age from tooth wear in one population does not necessarily apply to another population. Unfortunately, all the dentitions within a population do not wear at the same rate because of individual differences in diet and tooth structure. This severely limits the

accuracy of age estimation by this method, and other criteria should be consulted whenever possible.

The following is Brothwell's (1965) age classification based on wear patterns on premedieval British teeth (Figure 187).

Occlusion

The type of occlusion that exists between the maxillary and mandibular teeth has been of interest to anthropologists (Figure 188). In adult skulls, Mongoloids most frequently exhibit edge-to-edge occlusion of the teeth (Figure 188a). In contrast, Caucasoids most frequently display a slight overbite so that the maxillary incisors project more anteriorly than those of the mandible (Figure 188b). Underbites are uncommon in all racial groups (Figure 188c).

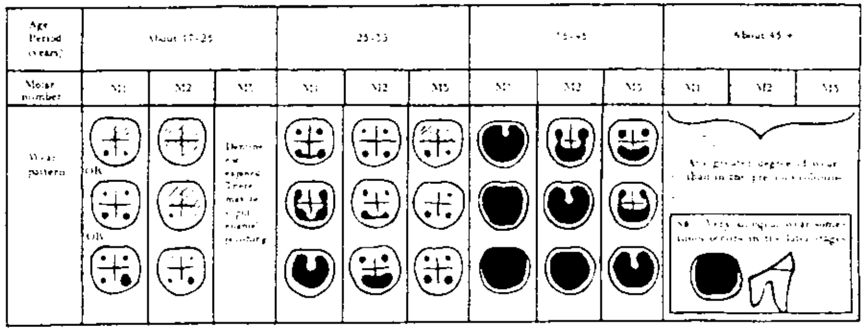


Figure 187. Correlation of age at death with molar wear in premedieval British skulls (after Brothwell 1965:69). Permission for reproduction granted by D. R. Brothwell and the Trustees of the British Museum of Natural History.

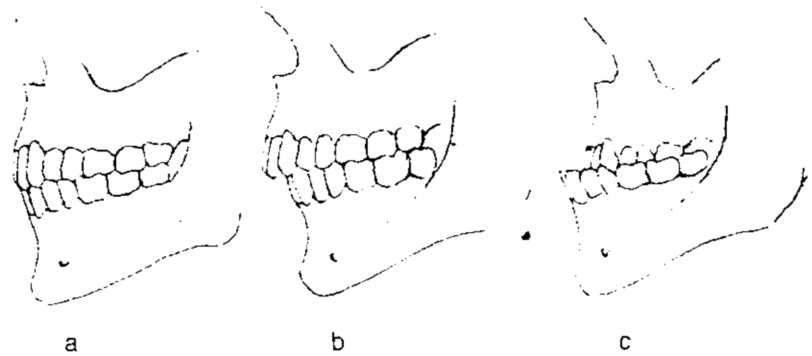


Figure 188. Occlusion of maxillary and mandibular teeth: a, edge-to-edge bite; b, overbite; c, underbite.

Artificial Deformation

Several features of tooth morphology may be attributed to cultural sources. In some cases the teeth have been filed or chipped intentionally to produce an ornamental effect. Dental mutilations in America have been classified into seven types by Romero (1958). These principally were found in Mexico. Several earlier studies discuss the world distribution of dental mutilation, reasons for its practice, and techniques involved. They describe mutilations from Africa, Australia, Malaya, and Egypt in addition to the examples from the New World. The incisors are the teeth usually involved, since they are the teeth most visible from outside the mouth.

Ubelaker *et al.* (1969) have reported the occurrence of artificial grooves located interproximally in the molar regions of several American Indian populations. These grooves usually occur near the junction of the crown and root of the tooth involved (Figure 189). The frequent association of these grooves with carious lesions, alveolar abscesses, and alveolar resorption resulting from periodontal disease suggest that these grooves were produced in an attempt to relieve discomfort in the immediate area. The investigators observed the phenomenon in material from archaeological sites geographically distributed over much of the United States and temporally distributed from the Archaic period to the present. This type of deformation is overlooked easily, and care should be taken to describe its occurrence.

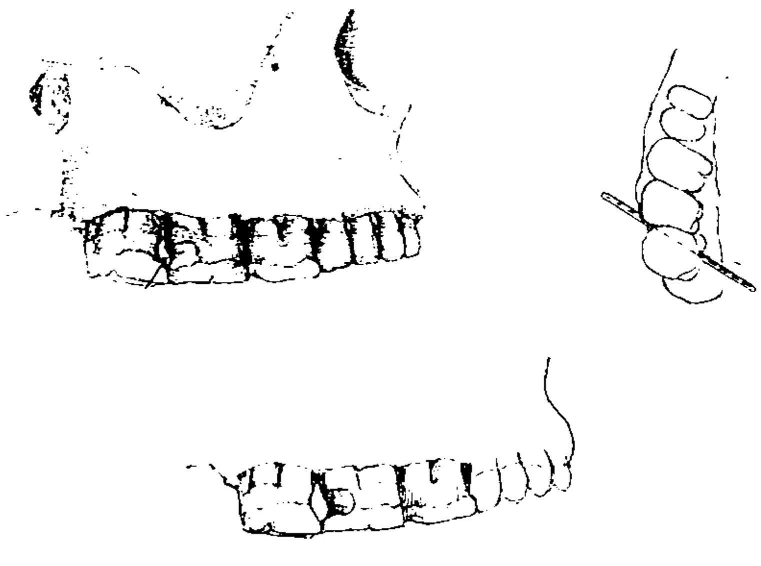
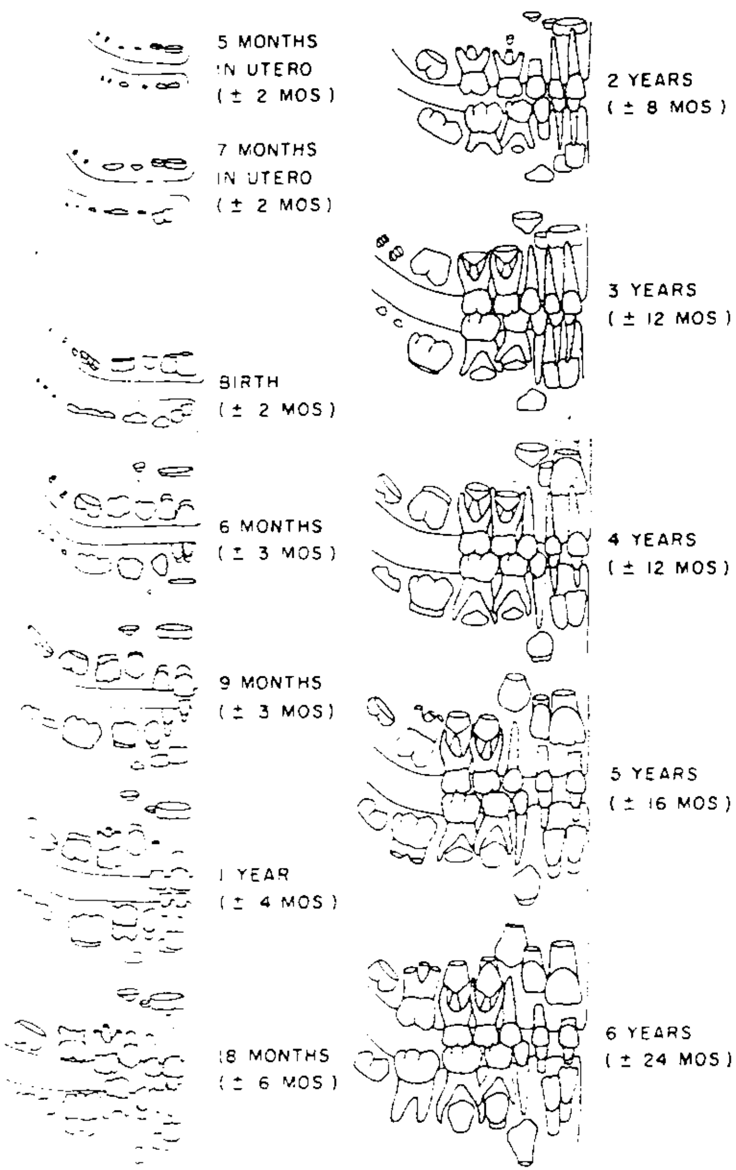


Figure 189. Variation in artificial deformation: interproximal grooves.

Dental Development

One of the more accurate indicators of chronological age through approximately age 12 is dental calcification and eruption. Numerous studies and a few charts have been produced by which subadult dentition can be compared. One of the best documented and current charts was compiled by Ubelaker (1978) (see Figure 190).



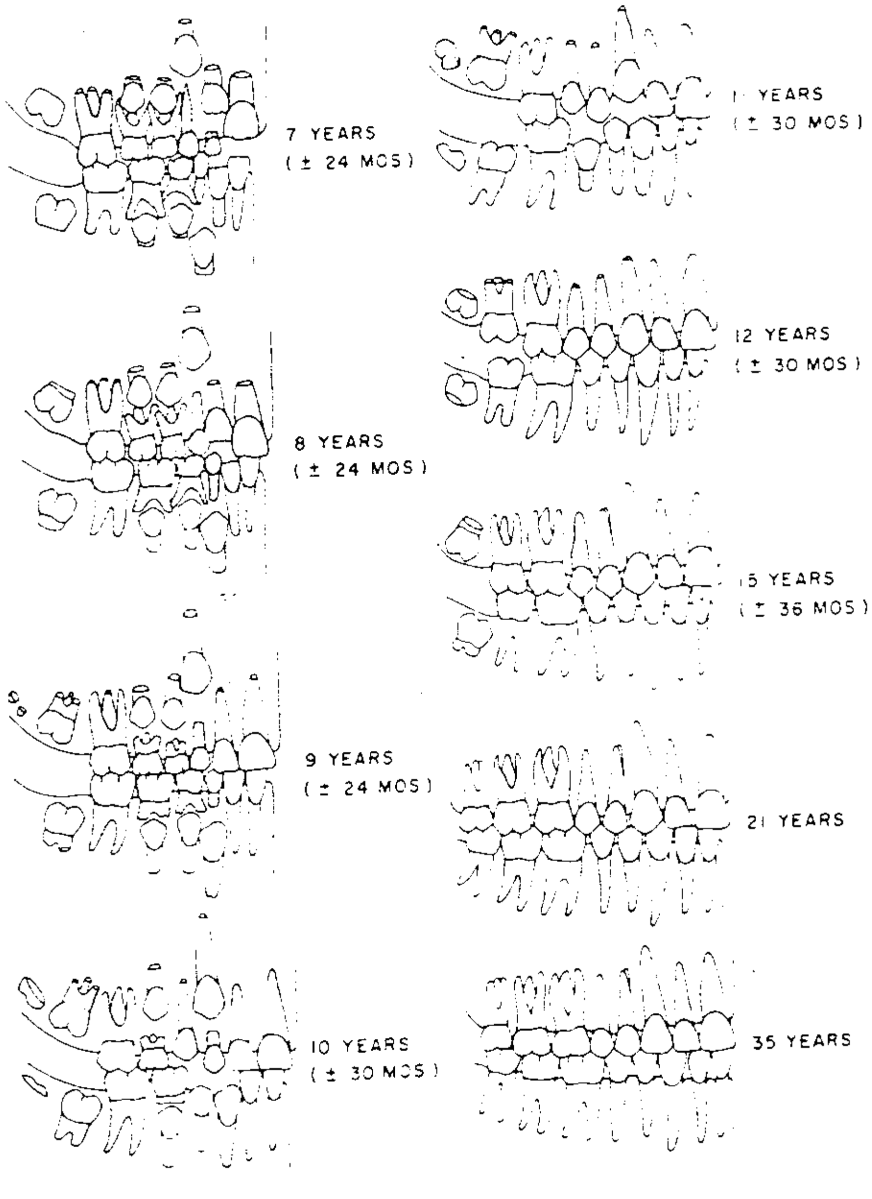


Figure 190. The sequence of formation and eruption of teeth among American Indians (from Ubelaker 1978:Figure 62). These changes are the most accurate method of establishing the age of adult individuals at death. Stippling indicates deciduous teeth.

APPENDIX 1
GLOSSARY AND MISCELLANEOUS INFORMATION FOR THE OSTEOLOGY STUDENT

CLASSIFICATION OF BONES ACCORDING TO SHAPE

LONG BONES—such as the femur, humerus, and radius consist of a shaft (or diaphysis) and two extremities (or epiphyses).
SHORT BONES—such as those of the metacarpus (hand) and metatarsus (foot) consist of a shaft and two extremities and sometimes are referred to as long bones in miniature.
FLAT BONES—such as those of the skull, scapulae, and innominates having relatively extensive surfaces for protection or for muscular attachment.
IRREGULAR BONES—such as the vertebrae, and the maxillary and sphenoid bones. These have irregular and often very complex shapes.

PARTS OF BONES

ALA—a winglike structure
APOPHYSIS—a prominence formed directly upon a bone
CANAL—narrow passage or channel
CAPITULUM—a small, rounded articular end of a bone
CONDYLE—a rounded projection on a bone usually for articulation with another bone
CONOID—cone shaped
CORONOID—shaped like a crow's beak
CREST—a sharp border or ridge
DENS—a tooth
DIAPHYSIS—the shaft of a bone
DIPLOË—latticelike bone, e.g., tissue between the tables of the skull
EPICONDYLE—above a condyle
EPIPHYSIS—the extremity of a bone expanded for articulation
FACET—a small, smooth area on a bone
FORAMEN—a hole
FOSSA—a depression
FOVEA—a pit or cuplike depression
GLENOID—having the appearance of a socket
HEAD—a rounded, smooth eminence for articulation
INCISURE—a notch
LIP—margin of a groove, crest, or line
METAPHYSIS—a line of junction between epiphysis and diaphysis
PIT—a tiny hole or pocket
PROCESS—any kind of projection
PROMONTORY—a projecting part
RIDGE—a rough, narrow elevation extending some distance
SINUS—a bone cavity lined with mucous membrane
SPINE—a sharp prominence

STRIA—a line
STYLOID—resembling a stylus
SULCUS—a groove
SUTURE—a form of articulation found only in the skull
TROCHANTER—a large prominence for attachment of rotator muscles
TROCHLEA—a pulley
TUBERCLE—a small tuberosity
TUBEROSITY—a rounded eminence

DEFINITIONS OF OSTEOLOGICAL TERMS

ACETABULUM—cavity on external surface of hip bone for head of femur
ACROMION—tip of shoulder
ASTRAGALUS—ankle bone
ATLAS—first cervical vertebra
AURICULAR—sacroiliac articulation
AXIS—second cervical vertebra
BASILAR—suture on base of skull between the occipital and sphenoid
BOSS—a rounded eminence
CALCANEUS—heel bone
CAPITATE—head
CARPUS—wrist
CERVICAL—neck
CHONDRAL—pertaining to cartilage
CLAVICLE—key; collar bone
COCCYX—tail bone
CONCHA—shell
CORACOID—like a crow's beak
CORONAL—suture between the frontal and parietals
CORPUS—body
COSTA—rib; side
COXA—hip
CUBOID—cubelike
CUNEIFORM—wedge shaped
DIGIT—finger or thumb
ETHMOID—sievelike
EPISTROPHEUS—second cervical vertebra
FEMUR—thigh bone
FIBULA—brace bone
HAMATE—hooked
HUMERUS—upper arm bone
HYOID—U-shaped bone
ILIUM—hip; haunch
INCUS—anvil
INNOMINATE—unnamed
INTEROSSEOUS—occurring between bones
ISCHIUM—hipbone
LACRIMAL—tear
LAMBDOIDAL—suture between the occipital and parietals
LINEA ASPERA—longitudal ridge on the posterior surface of the femur
LUMBAR—loin
LUNAR—moon shaped
MALAR—cheek
MALLEOLUS—little hammer
MALLEUS—hammer
MANDIBLE—lower jaw
MANUBRIUM—handle
MASTOID—breastlike
MAXILLA—upper jawbone
MEATUS—an opening
MENTAL FORAMEN—on the body of the mandible
METACARPAL—beyond the wrist
METATARSAL—beyond instep
MULTANGULAR—many angles
NASAL—nose
NAVICULAR—boat shaped

NUTRIENT FORAMEN—hole in a bone through which nutrients are received
OBTURATOR—the major foramen of the hip bone
OCCIPITAL—base of head
OCCLUSAL PLANE—masticating surfaces of the teeth
OLECRANON—ulnar process at the elbow
ORBIT—bony socket containing the eye
PALATE—roof of mouth
PARIETAL—wall; PATELLA—knee pan
PELVIS—basin
PHALANGES—line of soldiers
PISIFORM—pea shaped
POPLITEAL—posterior surface of the knee
PUBIS—pubic bone
RADIUS—spoke or ray
RESORPTION—removal by absorption
SACRUM—holy bone
SAGITTAL—arrow shaped; straight
SCAPHOID—boat shaped
SCIATIC—a notch in the hip bone
SEMILUNAR—half-moon shaped
SESAMOID—an oval bone nodule
SPHENOID—wedge shaped
SQUAMOSAL—platelike
STAPES—stirrup
STERNUM—breast bone; flat
STYLOID—long and pointed
SUSTENTACULUM—a support
SYMPHYSIS—a point of junction
TALUS—ankle bone
TARSUS—instep
TEMPORAL—time; instep
THORAX—chest; cage
TIBIA—shin bone; flute
TRAPEZIUM—little table
TRAPEZOID—tablelike
TRIQUETAL—triangular
ULNA—elbow
VERTEBRA—to turn; spindle
VOMER—ploughshare
XIPHOID—swordlike
ZYGOMATIC—cheek

TERMS INDICATING THE SIDE AND DIRECTION OF THE PARTS OF THE BODY

ANTERIOR—in front
AXILLARY—toward the armpit
CAUDAL—toward the tail
CRANIAL—toward the head
DISTAL—farthest from center
DORSAL—back
EXTERNAL—outside of
FRONTAL—in front
INFERIOR—lower
INTERNAL—inside of
LATERAL—to the side, away from the midline
MEDIAL—toward the midline
PLANTAR—sole of the foot
POSTERIOR—behind
PROFUNDUS—deep
PROXIMAL—nearest the center
RADIAL—lateral view of the metacarpals
SUPERFICIAL—near the surface
SUPERIOR—above
TRANSVERSE—crosswise
ULNAR—medial view of the metacarpals
VENTRAL—in front
VERTEX—top
VOLAR—relating to the palm or sole of the foot

BONES AND THEIR PLURALS

NAME OF BONE	PLURAL
Cranium	
ethmoid	ethmoids
frontal	frontals
occipital	occipitals
palate	palate bones
parietal	parietals
sphenoid	sphenoids
temporal	temporals
Face	
concha	conchae
lacrimal	lacrimals
mandible	mandibles
maxilla	maxillas or maxillae
nasal	nasals
vomer	vomers
zygomatic (malar)	zygomatics (malars)
Ear	
hyoid	hyoids
incus	incudes
malleus	mallei
stapes	stapeses
Vertebral Column	
coccyx	coccyges
sacrum	sacra
vertebra	vertebrae
Thorax	
gladiolus	gladioluses or gladioli
manubrium	manubriums or manubria
rib	ribs
sternum	sterna or sternums
xiphoid	xiphoids

Upper Extremities	
capitate	capitates
carpal	carpals
clavicle	clavicles
greater and lesser multangular	multangulars
hamate	hamates
humerus	humeri
lunate	lunates
navicular	naviculars
phalanx	phalanges
pisiform	pisiforms
scapula	scapulae
triquetrum	triquetrums
ulna	ulnae
Lower Extremities	
calcaneus	calcaneuses or calcanea
cuboid	cuboids
cuneiform	cuneiforms
femur	femora
fibula	fibulas or fibulae
ilium	ilia
innominate	innominates
ischium	ischia
patella	patellae
pubis	pubes
symphysis	symphyses
talus	tali
tarsal	tarsals
tibia	tibias or tibiae
Other Terminology	
foramen	foramina
epiphysis	epiphyses
process	processes
ala	alae
pelvis	pelves
stria	striae
alveolus	alveoli

WORD ANALYSIS FOR STUDENTS IN SCIENCE

A. Prefixes

A prefix is a short word form used at the beginning of a word to modify the meaning of a word. Often the spelling of a prefix is changed to make pronunciation easier. For example, the Latin prefix *ad-* is changed so that instead of adpendage we have appendage. Some of the most common prefixes used in biological terms are derived from Old English, Greek, and Latin, and are listed below with some variations in spellings, meanings, and examples.

Prefix	Meaning	Examples
	From Old English	
fore-	before, in front	forearm
un-	not	unconscious
	From Greek	
a-, an-	without, lacking	asexual, anaerobic
amphi-	on both sides	amphibian
ana-	up	anatomy
anti-	against	antiserum
cata-	down	catabolism
dia-	through	diaphragm
epi-	over	epidermis
hyper-	excessive	hyperthyroidism
hypo-	under	hypothalamus
meta-	after, change	metaphase, metamorphic
para-	beside	parabasal
peri-	around	perianth
pro-	for, before, in front of	pronotum
syn-, sym-, sys-	together	synapsis, sympetalous, systole
	From Latin	
ab-, abs-	from, away	abduct, abscess
ad-, af-, ag-	toward, to	adduct, afferent, agglomerate
bi-	two	bifocal
circum-	around	circumflex
com-, con-	with	commensal, conjugation

Prefix	Meaning	Examples
de-	down, away from,	depressed
dis-, dif-	separation	disarticulation,
	away, apart	diffusion
ex-, ef-		extraction,
	out, from	efferent
extra-	outside	extracellular
in-, im-	in, within	inclusion, immersion
in-	not	incapacitate
inter-	between	internode
intra-	within	intracellular
ob-, oc-	over, toward	obtected, occulsion
post-	after	postscutellum
pre-	before	prenatal
pro-	fo, before, in front of	prophase
re-	back, again	regression, refracture
semi-	half	semicircular
sub-, sus-	under	subcutaneous, suspend
super-, supra	over, extra, above	supersensitive, suprarenal
trans-	across	transpiration
ultra-	beyond	ultrasonic

B. Roots

A root is a word form that cannot be analyzed and has a relatively constant form and meaning. It sometimes is difficult to distinguish between prefixes and roots, but a root usually is more important and may be found at various positions in a word. If you know the meaning of a word's root or roots you often may obtain a general idea of the meaning of that word. Most of the roots used in biological terms are derived from Latin or Greek. Scientists have made use of both Greek and Latin roots to form combinations to produce new words for previously unknown phenomena. There are often meaningless, short connectives between word parts such as in the word chromosome which can be analyzed as: chrom-, color; -o-, the meaningless connective; and -soma, body.

The following list contains some of the more common Greek and Latin roots used as a basis for biological terms. The root, meaning, and examples are given.

Root	Meaning	Examples
	From Greek	
-anthrop-	man	anthropomorphic
-aster-	star	Asteroidea
-auto-	self	autonomic
-bio-	life	biogenesis
-chrom-	color	chromatin
-chloro-	green	chloroplast
-cyto-	cell	cytology
-derm-	skin	dermis
-ecto-	outside	ectoplasm
-endo-	within	endodermis
-gastro-	stomach	gastrovascular
-hem-	blood	hemolysis
-hetero-	different	heterozygous
-homo-	same	homologous
-hydr-	water	hydrobiology
-leuco-	white	leucocyte
-mega-	large	megaspore
-meso-	middle	mesoglea
-micr-	small	microscope
-mon-	one	mononucleate
-morph-	form	morphology
-orth-	straight	Orthoptera
-phor-	bearing	Mastigophora
-phot-	light	photosynthesis
-plasm-	a thing molded	endoplasm
-pod-	foot	Gastropoda
-poly-	many	polymorphism
-proto-	first	protoplasm
-pseud-	false	pseudopodium
-pter-	wing	Hymenoptera
-som-	body	somatic
-tri-	three	triploid
-zo-	animal	zoology

Root	Meaning	Examples
	From Latin	
-ac-	sharp	acute
-aqu-	water	aqueous
-aud-	hear	auditory
-brev-	short	brevicornis
-capit-	head	capitulum
-carn-	flesh	carnivore
-cid-, -cis-	kill, cut	insecticide excise
-corp-	body	corpuscle
-dec-	ten	Decapoda
-dent-	tooth	dentate
-duc-	lead	adduct
-flor-	flower	flora
-gen-	origin, kind	gene, genus
-loc-	place	locus
-mar-	sea	marine
-multi-	many	multiple
-mut-	change	mutation
-nomen-	name	nomenclature
-omni-	all	omnivorous
-ped-	foot	millipede
-seg-, -sect-	cut	segmental, dissection
-spir-	breathe	spiracle
-terr-	land	terrestrial
-uni-	one	unicellular
-vac-	empty	vacuum
-vol-	wish	voluntary
-volv-, -volu-	roll, turn	Volvox, evolution

APPENDIX 2

EXCAVATION AND TREATMENT OF SKELETAL REMAINS

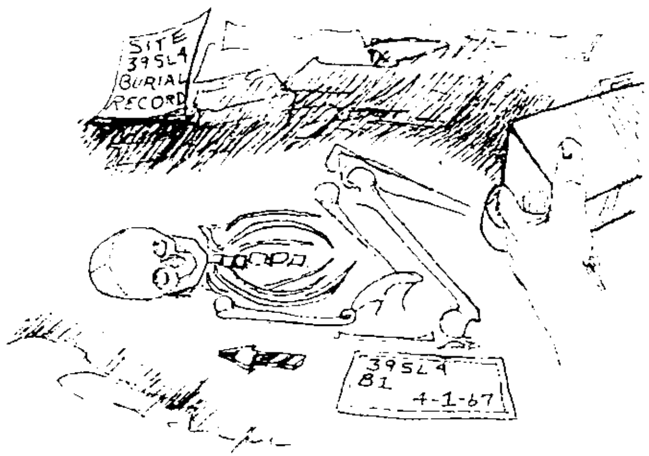
One of the major reasons for a manual such as this one is to teach students some of the proper procedures that always should be followed when (1) excavating, (2) transporting, (3) cleaning, (4) restoring, and (5) handling skeletal material. It is of equal importance to stress things that should never be done.

To some readers many of the things I will caution against may seem stupid, but they do occur. Much bone damage and mixing of skeletal material come from thoughtless actions. Always think of the consequences of your actions both in the field and in the laboratory.

EXCAVATION

Always:

1. Leave bones in place until entire skeleton is exposed.
2. Take photographs of exposed skeleton before removal.
3. Place markers for site and feature identification, direction (north arrow), and distance (centimeter or inch scale) alongside skeleton before photographing.
4. Keep accurate records. I have excavated more than 2500 burials and have used many types of record forms, but the most complete is that used by the River Basin Survey of the Smithsonian Institution. The form is reproduced with their permission on the following page. Gather the specified data when the complete skeleton has been exposed but before removal of any part. Do not rely on memory.



SMITHSONIAN INSTITUTION
RIVER BASIN SURVEYS
BURIAL FORM

Feature No. ____ Site No. ____
Burial No. ____ State ____
Reservoir ____ County ____

1. LOCATION
   a. Square ____
   b. Horizontal ____
   c. Depth from surface ____
   d. Depth from datum ____
2. BURIAL TYPE
   a. Extended ____ d. Reburial ____
   b. Flexed ____ e. Cremation ____
   c. Semiflexed ____ f. Part crem. ____
   g. Other ____
3. BURIAL DIMENSIONS
   a. Max. length ____ Dir. ____
   b. Max. width ____ Dir. ____
   c. Thickness ____
4. DEPOSITION
   a. Position ____
   b. Head to ____
5. GRAVE TYPE
   a. Surface ____ c. Cist ____
   b. Pit ____ d. Other ____
   e. Shape ____
6. GRAVE DIMENSIONS
   a. Max. length ____ Dir. ____
   b. Max. width ____ Dir. ____
   c. Depth ____
7. STRATIFICATION
   a. Inclusive ____ c. Precedent ____
   b. Intrusive ____ d. Disturbed ____
   e. ____
8. ASSOCIATIONS
   a. Features ____
   b. Specimens ____
9. PRESERVATION
   a. Poor ____ Fair ____ Good ____
10. COMPLETENESS ____
11. SEX
    a. M ____ F ____ Indeterminate ____
12. AGE
    a. Infant ____ d. Adult ____
    b. Child ____ e. Mature ____
    c. Adolescent ____ f. Senile ____
13. NEG. Nos. ____
14. REMARKS ____

Recorded by ____ Date ____

Site No. ____ Feature No. ____ Burial No. ____ Reservoir

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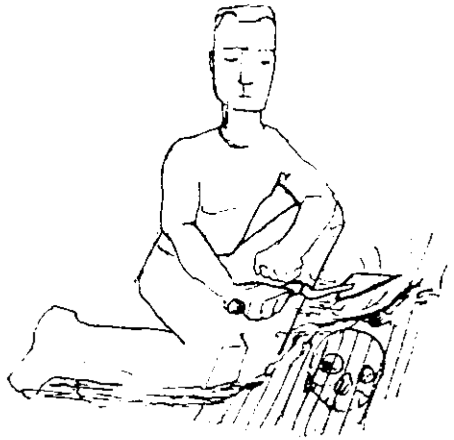
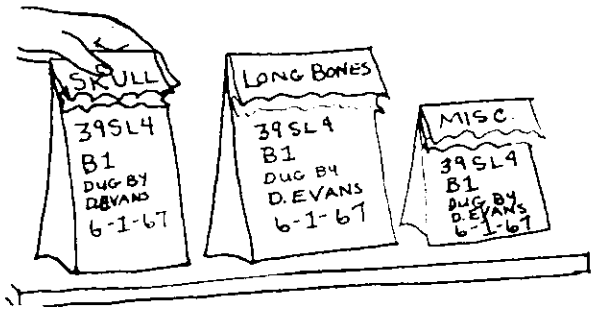


5. Use your trowel in a sweeping motion.
6. Place bones in marked containers (site number, burial number, feature number, date, excavator, etc.). Any container will do as long as it is carefully marked.
7. Use several bags to sack a complete skeleton: one for the skull and mandible; one for large bones (femora, tibiae, etc.); and one for small bones (vertebrae, ribs, etc.). By placing the bones of each hand and each foot in separate bags their subsequent identification will be facilitated.
8. Mark containers with waterproof ink.

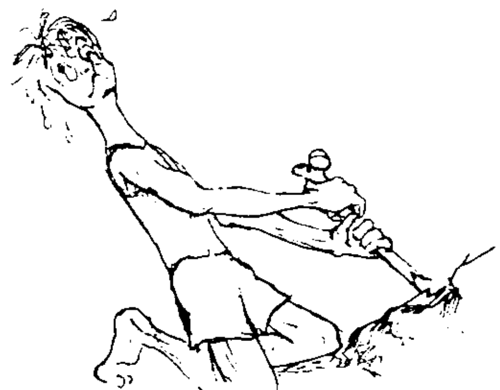


9. Use a small paint brush to remove as much dirt from the bones as possible at the time of recovery.
10. Allow wet bones to dry for a few hours in the shade before removal; damp bones are broken easily. Allowing bones to dry in direct sunlight, especially in midsummer, may cause longitudinal cracking.
11. Keep every piece of bone. Each piece aids in skeletal reconstruction and contributes to the accuracy of the analysis.

Never:

1. Stick a trowel into the ground to pry out bone. You cannot see what damage the end of the trowel is doing.
2. Leave dirt in the skull. It will harden, shrink, and act as a cannonball to crush the bone. Even if the skull breaks, it can be glued back together if all the pieces are kept.

3. Pull a partly exposed bone out of the ground. Wait until the skeleton is excavated completely. By removing the bone too soon you will not only lose scientific information but may break off the end. This will create more repair work later.

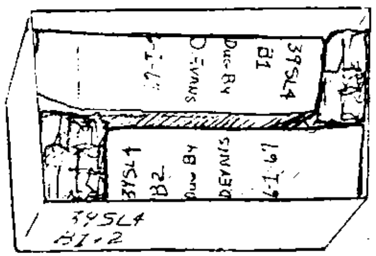


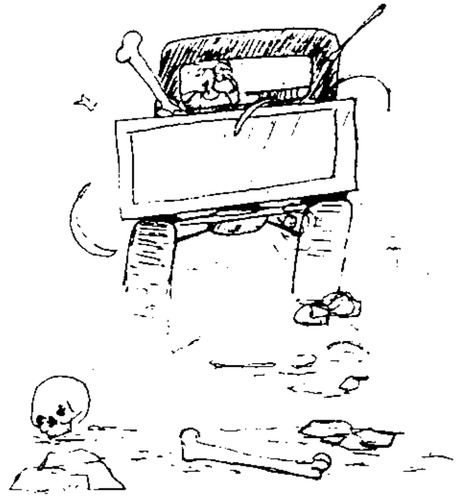
4. Place skeletal material in unmarked bags.
5. Treat bone with preservative of any kind in the field. Doing so will cause dirt to adhere to the bones and will necessitate extra work later in cleaning and restoration. If you wish to save bones or a skeleton *in situ*, remove by placing a plaster jacket around the bones and supporting earth. A water-soluble glue like Elmer's can be used on very fragile material.

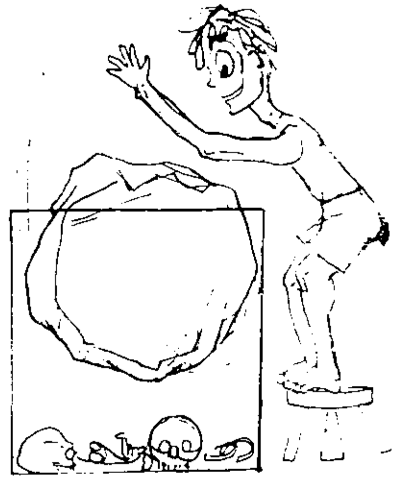
TRANSPORTATION

Always:

1. Pack marked bags of bones carefully. If bags are packed in a carton or box, place the open ends of the sacks at different ends of the box. If skeletal material is jarred out, it will then be easier to replace it in the proper sack.
2. Place the ones in small cartons with one or two burials to a carton when moving a large series of bones.
3. Take care to make sure bones will not shake out of bags or boxes and be lost or mixed.







Never:

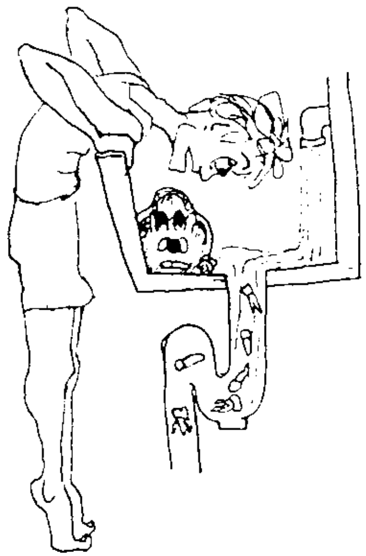
1. Toss bones in the back of a car or truck without proper packing and drive over rough roads.
2. Pack a series of skeletons in one large container (the size of a refrigerator, stove, or deep freeze).
3. Pack rocks or heavy artifacts on top of bones.

CLEANING

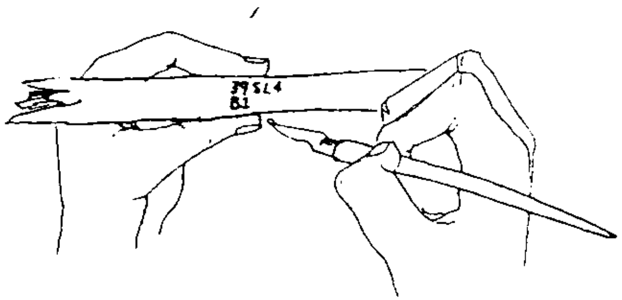
Always:

1. Clean material thoroughly over a screen-bottomed tray using water or acetone with a brush (typewriter brush, paint brush, etc.). If you use a tooth brush, do not use one with nylon or plastic bristles. Method of cleaning will depend on the condition of the bone. If the bone is solid, hard, and in good condition, wash it in water with a soft brush. If the bone is moist, soft, and flaky, allow it to dry under a fan, and brush dirt from the surface.

2. Be careful when washing or cleaning bones and teeth not to lose them down the drain. Always use a screen-bottomed tray. Teeth are easily lost.

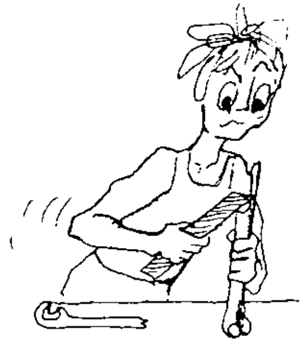


3. Label every cleaned bone with site number, burial number, catalog number, or some appropriate designation, so that material will not become mixed. Use waterproof ink.



Never:

1. Damage joints by rough brushing while attempting to remove dirt that is hard to get at.
2. Wash more than one skeleton at a time, as mixing of the material may result.



3. Sand or file off broken edges to make them join.
4. Glue a tooth in a socket until the wear surfaces are matched (that is if there *is* a wear surface; loss of teeth may eliminate this valuable aid).

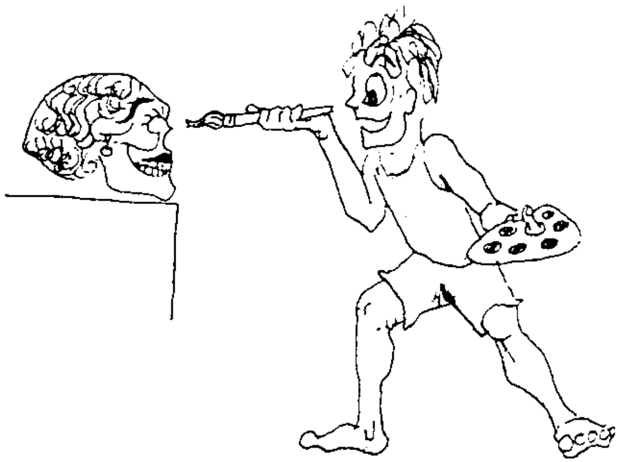
RESTORATION

Always:

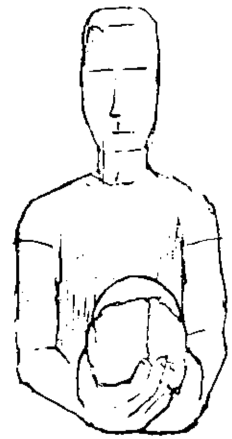
1. Wait until all of the bones are dry. When they are dry, broken bones can be restored by gluing them together with Duco cement or Ambroid (water-soluble glues are not recommended because they absorb moisture and allow the pieces to come apart). A box or pan of fine sand is needed to support the mended bones while the glue is hardening. Modeling clay, plasticene, wooden matchsticks, and light wire can be used to support the mended bones when necessary.
2. Assemble smaller parts into larger pieces and then fit the larger pieces together.
3. Be absolutely certain that you are gluing together the right pieces. Color and texture of the pieces should be considered in matching broken edges.
4. Label all bones at the end of the cleaning process.
5. Follow cleaning and restoration of the bones with dipping them in a transparent preservative such as Alvar, Duco, Ambroid, or Gelva. The mixture should be the consistency of water.

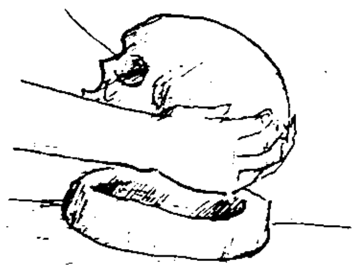
Never:

1. Work on more than one skeleton at a time unless all the bones are numbered properly. This will eliminate commingling of bones from different skeletons.
2. Fill in broken areas with plaster or plastic wood. This may cover evidence for pathologies or cultural practices such as cut marks on bones.
3. Cover bones with oil, paint, or shellac, as this obscures or covers up suture patterns and possible pathological processes.
4. Glue together unclean edges.
5. Use rubber cement to glue bones together because it rapidly loses its adhesive property.



HANDLING





Always:

1. Handle any bone carefully.
2. Handle skulls with both hands; never put fingers in eye orbits.
3. Use a bean bag or donut ring when placing the skull on a table.
4. Replace bones in their proper storage location.

Never:

1. Pick up the skull by the eye orbits.
2. Drop bones—they break!
3. Walk into a laboratory and pick up any item—bone or artifact unless you ask permission. If you pick up the bone from an assortment on a table, keep a finger on the spot it came from to avoid replacing it in the wrong location.

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INDEX

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- Received the Ph.D. in anthropology in 1961 from the University of Pennsylvania
- Choice of the national Council for Advancement and Support of Education for Professor of the Year in 198[illegible]
- Teacher educating one-half of board-certified anthropologists practicing human identification in the United States
- Researcher helped the University of Tennessee assemble a comparative skeletal collection second only to that housed at the Smithsonian Institution
- Public servant positively identifying the remains of approximately 300 crime and accident victims for law enforcement agencies throughout the nation
- Administrator guiding his department to a position of national [illegible] nence in forensic anthropology
- Philanthropist donating his fees from law enforcement [illegible] contingency fund for student financial support
- Public speaker each year addressing [illegible] the university [illegible] the University [illegible] Association [illegible]